

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

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1. REPORT DATE (DD-MM-YYYY) 09-2003		2. REPORT TYPE Annual Report		3. DATES COVERED (From - To) 08-2002 to 05-2003	
4. TITLE AND SUBTITLE ANNUAL REPORT OF THE OPERATIONS RESEARCH CENTER AND DEPARTMENT OF SYSTEMS ENGINEERING FOR ACADEMIC YEAR 2003				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S) COLLABORATIVE EFFORT OF THE DEPARTMENT OF SYSTEMS ENGINEERING, ORGANIZED BY THE OPERATIONS RESEARCH CENTER				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Operations Research Center of Excellence Department of Systems Engineering US Military Academy Bldg. #752-Mahan Hall-Rm 305 West Point, NY 10996				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) Assistant Secretary of Army for Financial Management and Comptroller Army Pentagon Washington, DC				10. SPONSOR/MONITOR'S ACRONYM(S) ASA (FM&C)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION / AVAILABILITY STATEMENT Distribution A - Approved for Public Release - Distribution Unlimited					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT n/a					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF: a. REPORT Unclassified			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON COL William K. Klimack
b. ABSTRACT Unclassified				84	19b. TELEPHONE NUMBER (include area code) 845-938-5529
c. THIS PAGE Unclassified					



**United States Military Academy
West Point, New York 10996**

**ANNUAL REPORT
OF THE
OPERATIONS RESEARCH CENTER
AND
DEPARTMENT OF SYSTEMS
ENGINEERING
FOR
ACADEMIC YEAR 2003**

DTIC Report #: ADA-xxxxxx

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Operations Research Center of Excellence**

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Professor and Head,
Department of Systems Engineering**

SEPTEMBER 2003

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Dean of the Academic Board, United States Military Academy**

20031223 029

The Operations Research Center is supported by the
Assistant Secretary of the Army (Financial Management & Comptroller)

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PART I - The Operations Research Center of Excellence (ORCEN)

Purpose of the Operations Research Center

The purpose of the Operations Research Center is to provide a small, full-time analytical capability to both the Academy and the United States Army. The Operations Research Center helps to fill several Academy needs:

- 1) enriched education for cadets;
- 2) enhanced professional development opportunities for Army faculty;
- 3) strong ties between the Academy and Army agencies; and
- 4) the integration of new technologies into the academic program.

By being fully engaged in current Army issues, the Operations Research Center assures that systems engineering education at West Point remains current and relevant. The one-year experience tour with the ORCEN offers officers assigned to the Academy as faculty the opportunity to engage in meaningful applied research and problem solving activities that both further enhances their soldierly professional development and keeps them current in their discipline. The Army's return on its investment is meaningful career development experiences for officers, especially those in Functional Areas 49/51/53, and important investigation of vital Army problems at far less cost than would be required through civilian contracts.

Operations Research Center projects provide the faculty and cadets with the opportunity to investigate a wide spectrum of interdisciplinary, systemic issues and to apply many of the systems engineering, engineering management, and operations research concepts studied in the classroom to real-world problems of interest to the Army. These projects demonstrate for both cadets and faculty the relevance and importance of systems engineering in today's high technology Army.

Organization of the Operations Research Center

Personnel authorizations in the ORCEN are established by a Table of Distribution and Allowances (TDA). Funding support for the Operations Research Center is established by a Memorandum of Agreement with the Office of the Assistant Secretary of the Army (Financial Management & Comptroller). The Operations Research Center is organized under the Office of the Dean as an Academy Center of Excellence. A permanent Military Academy professor provides oversight and supervision to the Center. In addition, the TDA authorizes one analyst, O5; three analysts, O4; and one secretary, GS5. By agreement between the Department of Systems Engineering (D/SE) and the Department of Mathematical Sciences (D/MATH SCI), three analysts are assigned to the ORCEN by D/SE, and one analyst comes from the D/MATH SCI. The Department of Systems

Engineering also provides the permanent faculty member to serve as the Director. The Operations Research Center welcomes the opportunity to collaborate on Army-related projects with USMA teaching faculty from the Departments of Systems Engineering, Mathematical Sciences, and others. In addition, the ORCEN is able to provide Army officers attending graduate school and cadets enrolled in advanced individual study courses with real-world projects that are well suited for either thesis work or course projects. This in turn provides Army agencies with a greater range of expertise to address a wide spectrum of projects.

The Operations Research Center occupies office and laboratory space in the Department of Systems Engineering on the third floor of Mahan Hall. The Center includes offices for the director and analysts, and a briefing area. The Department of Systems Engineering laboratories -- Combat Simulation, Systems Management and Design, Computer Aided Design, and Installation Management and Engineering -- are located within easy access to the Operations Research Center.

The Operations Research Center is sponsored by the Assistant Secretary of the Army (Financial Management & Comptroller). Fully staffed and funded since Academic Year 1990-1991, the Operations Research Center has made significant contributions to cadet education, faculty development, and the Army at large.

Personnel

The following is a list of the Operations Research Center positions and personnel assigned during FY03:

ACADEMIC RANK & ORGANIZATION	NAME	PHONE	EMAIL
Professor & Head, DSE:	COL Michael L. McGinnis, Ph.D.	688-2701	fm0768@usma.edu
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These full-time analysts are augmented by permanent faculty who serve as senior investigators for each project, as well as by instructors from the Department of Systems Engineering, the Department of Mathematical Sciences, and other departments who work as primary analysts or co-analysts on ORCEN projects. Contributors for AY03 are listed in the following table.

ACADEMIC RANK & ORGANIZATION	NAME	PHONE	EMAIL
Professor	Patrick J. Driscoll, Ph.D.	688-6587	fp5543@iusma.edu
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Associate Professor	LTC Michael J. Kwynn, Jr., Ph.D.	688-5529	fm9536@usma.edu
Associate Professor	Lt. Col. Edward Pohl, Ph.D.	688-5168	fe6428@usma.edu
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Laboratory Resources

Systems Management and Design Lab (SMDL)

This lab is designed to facilitate group design work, ideation and sharing. Presentation and conferencing facilities are part of the lab. The principle function of the lab is to facilitate cadets working as groups as they move through the systems engineering design process, particularly the formulation and interpretation of alternatives steps. A secondary purpose is to provide a sophisticated meeting and briefing place for all kinds of groups with the capability to enhance their work. Lab equipment is designed to be reconfigurable to accommodate different size groups and organizations.

The lab's 18 workstations have Pentium III/Dual 933 MHz processors, 512 MB RAM, 18 GB hard drives, Diamond Fire GL1 video cards with 32 MB of RAM, and 18" flat panel displays. This capability allows cadets to use advanced software and peripherals for high-speed data processing and high quality graphics. One of these workstations is used as the facilitator's workstation while the others are nodes in the CSCW software package (GroupSystems V).

Installation Management and Engineering Annex

The Installation Management and Engineering Annex (IMEA) to the SMDL provides cadets and faculty with the tools needed to study installation management and power projection related issues. Engineering Management cadets use Geographic Information System (GIS) and other engineering analysis software in the Introduction to Systems Design for Engineering Managers (SE411) as well as in the follow-on capstone design

courses (SE421). Other cadets use the facility to conduct in-depth research in advanced individual study courses (SE 489).

The hardware configuration of the IMEA consists of 10 workstations which have Pentium III/Dual 933 MHz processors, 512 MB RAM, 18 GB hard drives, Diamond Fire GL1 video cards with 32 MB of RAM, and 18" flat panel displays.

Combat Simulation Laboratory

The Combat Simulation Laboratory (CSL) offers state-of-the-art simulation and analysis tools for virtual prototyping, testing and evaluation in distributed and non-distributed environments. Cadets combine premier Army simulations and commercial-off-the-shelf (COTS) modeling tools to gain insight into real-world Army problems. Cadets build a foundation in Combat Modeling (SE 485) and apply their knowledge in System Design I and II (SE 402/403) and in Advanced Individual Study in Systems Engineering or Engineering Management (SE 489). ORCEN analysts and department faculty use the facility to approach a variety of problems.

Janus, OneSAF TestBed, JCATS, and ITEMS are the primary simulations. JETS, the Janus Evaluator's Tool Set, is the main analysis tool and simulation browser. Simulation output may be analyzed directly through JETS or exported to a variety of other tools, such as Minitab. COTS tools include MultiGen Creator Pro 3D modeling software. Hardware includes an Onyx Infinite Reality computer, 5 Hewlett-Packard Unix computers, and 18 PC workstations with 2 GHz processors, 512 MB RAM, 40 GB hard drives and 17" flat panel monitors. All hardware is networked through a Cisco 6000 switch to the Internet via fiber optic cable.

Computer Aided Systems Engineering Laboratories I and II

Two identical CASE laboratory facilities provide 36 workstations for general support to DSE courses. Each workstation offers standalone simulation capability with packages including ProModel. Decision support packages including the PrecisionTree ToolSuite combine with analysis and optimization packages such as Premium Solver and MiniTab. Collaborative and active learning is enhanced through SynchronEyes, which allows student workstations to be shared throughout the classroom. Instructors also use SmartBoard touch technology projection screens.

These computers have 2 GHz processors, 512 MB RAM, 40 GB hard drives and 17" flat panel monitors.

Mobile Technology Classroom

The Mobile Technology Classroom (MTC) provides powerful, reconfigurable computing to any classroom. The full suite of DSE office and simulation software is installed on notebook computers with wireless local area network connections to enable any department course to utilize common applications in the classroom. Computers are housed in a high-security cart that provides a network access point, printer and recharging capability.

The computers contain 1.13 GHz Pentium III processors with 512 MB RAM, Nvidia video cards with 32 MB RAM, 2 batteries for 6-hour continuous operation, 20 GB hard drives, CD ROM and 100 Megabit internal LAN card and 802.11a wireless PC LAN cards.

PART II – Principal Research Activities – AY03

Benefits of Imagery Collection for Enhancing Intelligence Gathering (aka DAMTA)

DSE Project No: DSE-R-0301

Client Organization: Army Research Laboratory (ARL), Battlefield Environment Division

Principal Analyst: MAJ Gregory A. Lamm, M.S.
Senior Investigator: LTC James M. Buckingham, Ph.D.

Points of Contact:

NAME:	ADDRESS:	PHONE:	OTHER:
Ed Creegan (Client)	Director, Army Research Laboratory (ARL), Battlefield Environment Division, White Sands Missile Range	505.678.4684 505.382.7917	ecreegan@arl.army.mil
Mr. Ed Hume (Sponsor)	University Partnering for Operational Support (UPOS) Johns Hopkins University Applied Physics Laboratory		Edward.Hume@jhuapl.edu

Problem Statement:

Weather and other environmental data are critical information that affects the decision-making abilities commanders on the battlefield. The Disposable, Air-droppable, Meteorological Tower Array (DAMTA) consists of a sensor-based platform that will be dispersed over an area of interest and provide key weather data and images to enhance the accuracy of the current Army Forecast Models, provide information on remote areas of the battlefield, provide forecasting for future battlefield operations, and gather additional information about out of sector areas. The scope of the project was to explore the benefits of imagery and the integration of an imagery device on the DAMTA platform.

Scope of Work & Methodology:

Our purpose is to investigate the benefits of augmenting DAMTA with digital imagery sensors to collect near real-time images of weather conditions on the battlefield. The project consisted of the following tasks: 1) provide recommendations for off-the-shelf hardware that enhances DAMTA's platform capabilities, 2) explore DAMTA's imagery capabilities, and their application and integration in future military operations, 3) explore how imagery assists specific military communities and other disciplines, 4) analyze the benefits of imagery by researching the trade-offs, attributes, relationships and values that users place on the configuration of imagery-capturing devices, and 5) evaluate the vulnerabilities of imagery-based components on sensors in specific environments.

Results Summary:

We recommend placing three small cameras spaced 120 degrees apart near the top of the DAMTA "can." This configuration provides the best possible view, provides adequate coverage of the horizon, and optimizes the placement of sensors and electronics at the top of the platform. Having completed the MODA Matrix and the sensitivity analysis, the team recommends the MVC 3200 C Pinhole Camera as the best camera for the DAMTA application.

The final design provides several benefits: 1) it flush mounts the cameras with the outside of the DAMTA "can" minimizing damage to the cameras, 2) it allows sufficient room in the top of the DAMTA "can" for other standard sensor electronics and puts the cameras within four inches of the top of the DAMTA, and thus over 6 feet off the ground, for excellent visibility, 3) it provides a total panorama of approximately 180 degrees, which is half of the horizon and minimizes the effects of precipitation on the camera optics as pinhole cameras have no lens, and 4) it relieves the requirements for a separate modular "imagery sensor" piece and instead incorporates the cameras into the existing "can".

The benefits to integrating imagery within the DAMTA platform are that imagery: 1) can have a profound affect on accurately forecasting weather by visualizing, verifying raw weather data and enhancing the commander's knowledge about the tactical situation, 2) can increase situational awareness for commanders and staffs within specific environments, 3) can increase the trust they have in weather reports, 4) will show the impacts of weather, terrain and the environment on operations, and 5) will reduce loss of life during tactical operations by minimizing mission failures (*mission failure avoidance*), and providing the opportunity to plan and execute missions better than with only raw weather data.

Presentations and Publications:

- Lamm, Gregory, Dave Bunt and James Buckingham. *Benefits of Imagery Collection for Enhancing Intelligence Gathering*. 2003 Systems and Information Engineering Design Symposium. University of Virginia, VA. 2003.
- CDT Jacob Bailey, CDT Dave Bunt, CDT Chris Green and LTC Jim Buckingham. American Society of Engineering Managers (ASEM) 2002 Conference. Initial Findings.
- Buckingham, James, Gregory Lamm, Chris Green, Jacob Bailey and Dave Bunt. *Imagery Collection as an Enhancement to the Disposable, Air droppable, Meteorological Tower Array (DAMPTA) for Intelligence Gathering on the Battlefield*. ORCEN Technical Report NO. DSE-TR-03-01.
- CDT Jacob Bailey, CDT Dave Bunt, and CDT Chris Green. Hollis Award Presentation. May 2003.
- Buckingham, James, Gregory Lamm, Chris Green, Jacob Bailey and Dave Bunt. *Imagery Collection as an Enhancement to the Disposable, Air droppable, Meteorological Tower Array (DAMPTA) for Intelligence Gathering on the Battlefield*. American Society of Engineering Managers (ASEM) 2003 Conference. Final Presentation.

Personnel Briefed:

- Ed Creegan, Client. Army Research Laboratory (ARL), Battlefield Environment Division, May 2003.
- Walter W. Hollis, Deputy Under Secretary of the Army for Operations Research, May 2003.

Status: Complete.

Extended Range Multi-Purpose UAV

DSE Project No: DSE-R-0329

Client Organization: PEO Aviation, Redstone Arsenal, AL

Senior Investigator: Dr. Roger C. Burk, Ph.D.

Points of Contact:

NAME:	ADDRESS:	PHONE:	OTHER:
COL John D. Burke	Project Manager, Tactical Unmanned Aerial Vehicle Systems (PM-TUAVS) PEO Aviation Redstone Arsenal, AL 35898	256-895-4449	burkejd@tuav.redstone.army.mil
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Problem Statement:

PM-TUAVS requested that a cadet capstone group evaluate existing unmanned aerial vehicle systems to evaluate which of them best met the requirements for a proposed Extended Range / Multipurpose (ER/MP) tactical UAV.

Scope of Work & Methodology:

The cadets went over in detail a draft Operational Requirements Document annex that set the performance requirements for the proposed ER/MP UAV system. They identified the performance requirements that applied to the air vehicle, and based on them and on value information elicited from the client, they created an additive multiattribute value model for the ER/MP air vehicle. They then researched the capabilities of existing UAVs, as far as they were available to the public. These data were used to score each UAV against each attribute for which data were available, and the weighted scores were then added to produce total value scores, which gave a ranking of the alternatives and recommendation. Sensitivity analysis was used to evaluate the possible effect of missing data, and to investigate sensitivity of the final ranking to attribute weights.

Results Summary:

Eight UAVs were identified that passed feasibility screening. Based on available data on these aircraft, the highest value scores were achieved by the Predator B (from General Atomics Aeronautical Systems Inc.) and by the Heron (from Israeli Aircraft Industries). These two were very close in score, with Predator B having a slight edge.

The cadets were not able to score some aircraft in some attributes because the required data were not publicly available (e.g., survivability measures). Sensitivity analysis revealed that three other UAVs could possibly outscore the winners if all the unknowns turned out in their favor and against Predator B and Heron. These possibly competitive alternatives were Hermes 1500 (Silver Arrow), I-GNAT (General Atomics), and Predator (also General Atomics).

Sensitivity analysis on value weights showed that there would be no change in the winner for any foreseeable change in the weights, except in the case of the weight on a measure of size of the required landing strip. In this case, a small increase would result in Heron edging out Predator B for the top score.

Presentations and Publications:

- Burk, Roger C. Presentation at the Military Operations Research Society Symposium, Working Group 10 (Unmanned Vehicles): *Analysis of Alternatives for an Army Extended Range Multipurpose UAV*, Marine Corps Base Quantico, VA,

Personnel Briefed:

- COL John D. Burke (Program Manager, Tactical Unmanned Aerial Vehicle Systems), *UAV Capstone Project Client Briefing #3* – 21 April 2003
- MG Joseph L. Bergantz (Program Executive Officer, Aviation), *UAV Capstone Project Client Briefing #3* – 21 April 2003

Status: Complete.

High Energy Laser Weapons: Modeling and Simulation

DSE Project No: DSE-R-0302

Client Organization: High Energy Laser Joint Technology Office (HEL JTO)

Principal Analysts: MAJ Suzanne O. DeLong, M.S.

CPT Eric S. Tollefson, M.S.

Senior Investigator: Dr. Roger C. Burk, Ph.D.

Points of Contact:

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Glen P. Perram Professor of Physics	Department of Engineering Physics Air Force Institute of Technology 2950 P Street Wright-Patterson AFB, OH 45433-7765	(937)-255-3636 ext 4504	glen.perram@afit.edu

Problem Statement:

As part of the Joint Technology Office (JTO) High Energy Laser (HEL) Modeling and Simulation (M&S) study, we conducted an inventory and evaluated existing HEL M&S capabilities of Army combat M&S software packages to judge their applicability, utility, and limitations with respect to modeling HEL weapons. This was the first task in a multi-phase, multi-year project.

Scope of Work & Methodology:

We conducted document reviews, internet searches, and telephone interviews to identify Army combat simulations that included models of HEL weapons. Based on the results of this effort and on the unique Army requirements for modeling HEL weapons in ground warfare and air and missile defense scenarios, we narrowed our focus to a few of the existing models. On those models, we conducted a software study to determine the issues, implications, and limitations of integrating HEL weapons into the selected software packages.

Results Summary:

In EADSIM, the Army has a robust and proven HEL combat model for air and missile defense engagements. EADSIM models the physics of laser weapon at a medium level of fidelity. The simulation EADTB also contains a usable HEL weapon model for air defense engagements, but at a somewhat lower level of fidelity. However, the Army currently has no usable combat model for HELs in any other mission, such as a direct fire ground-to-ground role.

Presentations and Publications:

- DeLong, Suzanne O., Eric S. Tollefson, and Roger C. Burk. DSE Technical Report: *Modeling of HEL Weapons in Army Combat Simulations*, August 2003. Report No. DSE-TR-03-02 (DTIC #: ADA416997)

Personnel Briefed: None

Status: Continuing.

Accelerating the Hungarian Algorithm for Transportation Problems

DSE Project No: DSE-R-0306

Client Organization: The Department of Systems Engineering, US Military Academy,
West Point, NY

Principal Investigator: Patrick J. Driscoll, Professor, Ph.D.
Co-Principal Investigator: Hanif D. Sherali, Professor, Virginia Tech.

Problem Statement:

The classical assignment problem is to assign n jobs to n machines at the least total cost. This paper presents a modification to Kuhn's Hungarian Method that explicitly maximizes the underlying dual ascent obtained at each step. The modification is both simple and insightful. Since its introduction by Kuhn (1955), there have been only a small number of improvements to the Hungarian algorithm for solving the classical assignment problem given by

$$\text{Minimize } \sum_{i=1}^n \sum_{j=1}^n c_{ij} x_{ij} \quad (1)$$

$$\text{subject to: } \sum_{j=1}^n x_{ij} = 1, \quad i = 1, \dots, n, \quad (2)$$

$$\sum_{i=1}^n x_{ij} = 1, \quad j = 1, \dots, n, \quad (3)$$

$$x \geq 0. \quad (4)$$

The solution to the assignment problem (1)-(4) yields a minimum weighted perfect matching between the n jobs and n machines. Wright (1990) notes that although one might posit that simplicity requires no improvement, when a long series of successive assignments needs to be made (Wright, 1989), or such assignments appear as a subproblem to much more difficult problems (Hahn et al., 1998), even minor gains in computational efficiency can yield significant overall savings. Barring such improvements, researchers will turn to other algorithms to achieve efficacy. The labeling algorithm introduced by Lofti (1989) and the dual update method of Ping et al. (1997) are prime examples of this effect. The modification we propose is motivated by a desire to maximize the underlying dual ascent that is implicit during each iteration of the algorithm.

Scope of Work & Methodology:

Coding and computational testing of the proposed modification.

Results Summary:

Coding and computational testing in FORTRAN is on-going. Theoretical work is completed.

References:

- Hahn, P., T. Grant, and N. Hall. 1998. "A branch-and-bound algorithm for the quadratic assignment problem based on the Hungarian method," *European Journal of Operational Research*, 108, 629-640.
- Kuhn, H. W. 1955. "The Hungarian method for the assignment problem," *Naval Res. Logistics Quarterly*, 2, 82-97.
- Lofti, V. A. 1989. "A labeling algorithm to solve the assignment problem," *Computers and Operations Research*, 16, 397-408.
- Ping, J., W. B. Lee, and H. Li. 1997. "A new algorithm for the assignment problem: an alternative to the Hungarian method," *Computers and Operations Research*, 24, 1017-1023.
- Wright, M. B. 1989. "Applying stochastic algorithms to a locomotive scheduling problem, *J. Operational Research Society*, 40, 187-192.
- Wright, M. B. 1990. "Speeding up the Hungarian algorithm," *Computers and Operations Research*, 17, 95-96

A Design Space Branching Methodology for Systems Design for Redundancy

DSE Project No: DSE-R-0307

Client Organization: The Department of Systems Engineering, US Military Academy, West Point, NY

Principal Investigator: Patrick J. Driscoll, Professor, Ph.D.

Co-Principal Investigator: Edward Pohl, Lt. Col, Ph.D.

Problem Statement:

In this study we develop a mathematical programming based branching strategy for designing reliability redundancy into systems that uses a new fathoming heuristic which exploits both the discrete nature of the system reliability function and the variation contained in component reliability estimates to reduce the total design space. Current methods either directly face the extreme nonlinearity of the system reliability function or attempt to employ branching strategies directly on the decision variables without considering the inherent variation contained in the reliability estimates.

Scope of Work & Methodology:

- Examine the computational efficiency of design space branching on large-scale problems.
- Develop a new linearization strategy for the system reliability function that introduces a totally unimodular (TU) substructure into the linear constraints defining the problem.
- Determine the computational efficiency of the linearization strategy, exploring the options for tightening the polyhedral representation of the convex hull of design space variables.

Results Summary:

The problem setting under investigation was component selection for reliability redundancy in a parallel-series configuration. Adopting the approach that system reliability is a consequence of stage reliabilities, we constructed several representative system structures against which we could attempt a reliability maximization. For each system structure, we imposed a one-sigma interval characterizing the uncertainty of the least reliable component and bounded the improvement in stage reliability by this amount at the onset. This corresponds to a ‘weakest link’ philosophy. We then demonstrated that the subsequent enumeration branching in the design space rapidly collapses to an optimal design configuration at much earlier levels than other methods, solely due to the use of a one-sigma bound interval. In practical terms, this imposition cased a rapid and significant design space reduction. We further demonstrated that using the minimum variation on component reliability allowed for the most optimistic improvement while recognizing information limitations, and that the high reliability components amplify the pruning effect within the design space. Furthermore, we illustrated how this approach

encouraged linearization and discretization of the total system reliability function because the design space limitations impose a exploitable constraint structure on the problem.

Presentations and Publications:

- Driscoll, P.J.* and E. Pohl.* "A mathematical programming approach to reliability systems design." International Federation of Operational Research Societies (IFORS), Edinburgh, Scotland, July, 2002.

Status: On-going.

Modeling the Decision Quality of Sensor-to-Shooter Networks

DSE Project No: DSE-R-0308

Client Organization: The Department of Systems Engineering, US Military Academy,
West Point, NY

Principal Investigator: Patrick J. Driscoll, Professor, Ph.D.
Co-Principal Investigator: Edward Pohl, Lt. Col, Ph.D.

Problem Statement:

This study presents a methodology for representing the decision quality of STS networks involving unattended ground sensors (UGS) in terms of the uncertainty associated with the network information flow. Understanding the limitations imposed by this uncertainty provides design guidance for precision levels and information maintenance strategies that will improve the accuracy of the information used at various decision points in an STS network, including the fire/no-fire decision point.

Scope of Work & Methodology:

- Examine the quality of the information products manufactured by the devices and processes of a sensor network.
- Develop an information-based framework for assessing the decision quality of STS networks in terms of the uncertainty present at decision points.
- Develop metrics for sensitivity and analyze the sensitivity of STS networks to changes in uncertainty to develop prioritized information maintenance plans.
- Prescribe investment guidelines for precision based on diminishing marginal returns to the level of uncertainty at critical decision points in an STS network.
- Better understand the uncertainty ‘comfort zone’ used currently for decision making.
- Prescribe guidelines for threshold decision criteria for fully-automated STS networks.

Results Summary:

A new representation of a general support STS network within an information manufacturing framework based in part on the taxonomy of uncertainty introduced by Smets (1997), and the information quality decomposition of Eppler and Muenzenmayer (2001) and Wang, et.al (2001) was developed and presented at the conference noted below. Using this framework, we introduced a new definition of decision quality based on the percentage of uncertainty present at a decision point independent of the actual decision made, thereby uncoupling process outcome from action outcome. This definition of decision quality then allowed us to decompose an STS network in terms of the probability distributions associated with processes and parameters throughout the network.

We are currently working on characterizing important performance distributions involved with the sensor functions (detect, classify, operate, identify), and the algebraic operations that manipulate these distributions in the process of manufacturing information. These should produce closed-form analytical expressions for the distributions associated with aggregating sensors, the master node voting (k out of n) process, intermediate information products (IIP), and the final information product present at the decision point(s).

We have expanded our research group to include Dr. Michael Tortorella, Rutgers University, who has an extensive background in network reliability for Lucent Technologies. Using software previously developed by Dr. Tortorella, we intend to analyze the sensitivity of various statistical parameters describing the decision point distribution (the uncertainty involved with the decision point) to changes in number of sensors, mix of sensors, and precision levels of sensor functions. These results will then be integrated with the sensor performance tradeoff function results obtained by Lamm and Driscoll (2002) in order to propose equivalence measures and points of diminishing returns with regards to device precision and response levels of uncertainty.

Building on the stochastic network constructed previously, we are exploring the implications for future research and development on sensor precision and quantify the marginal benefits of performing specific information maintenance actions at various locations throughout the network.

Presentations and Publications:

- Driscoll, Patrick J., and Edward Pohl. 2002. "Modeling the Decision Quality in Sensor-to-Shooter (STS) Networks for Unattended Ground Sensor Clusters." *Proceedings of the Seventh International Conference on Information Quality*, Massachusetts Institute of Technology, Cambridge, MA.
- Driscoll, P.J.* , and E. Pohl.* "Modeling the Decision Quality in Sensor-to-Shooter (STS) Networks for Unattended Ground Sensor Clusters." *Seventh International Conference on Information Quality (ICIQ)*, MIT, Cambridge, Massachusetts, November, 2002

Status: On-going.

References:

- Smets, P. "Imperfect information: imprecision and uncertainty." In A. Motro and P. Smets, editors, *Uncertainty in Information systems: From Needs to Solutions*, Kluwer, Boston, MA, 1997, pp. 225 – 254.
- Eppler, M. and P. Muenzenmayer. "Measuring information quality in the web context: a survey of state-of-the-art instruments and an application methodology," *Proceedings of the Seventh International Conference on Information Quality*, Massachusetts Institute of Technology, Cambridge, MA, 2001.
- Wang, R.Y., M. Ziad, and Y.W. Lee. *Data Quality*, Kluwer Academic Publishers, Boston, MA, 2001.

Modal Logic and Sensor Information Fusion

DSE Project No: DSE-R-0317

Client Organization: The Department of Systems Engineering, US Military Academy,
West Point, NY

Principal Investigator: Patrick J. Driscoll, Professor, Ph.D.
Co-Principal Investigator: CPT Steven Henderson, M.S.

Problem Statement:

A Sensor-to-Shooter network is a closed-loop, internal feedback targeting system that links various suites of sensors deployed throughout a three dimensional battlespace to a network of weapons platforms using optimized communication pathways. A fully-automated STS network can be decomposed into three major segments: target acquisition, a fires commitment decision process, and a weapons engagement process. Targets are detected, classified and identified at the sensor end of the network. A decision support system then determines if a threshold criteria for target identification has been met, and if so, makes the decision to commit the appropriate available weapons platform(s) to engage the target. Once handed the fire mission, the weapons platform would engage the target and the sensors would subsequently assess the damage. The decision support system would then compare target damage to threshold criteria, and re-engage as necessary.

Designing such a system for general support of operational forces is tricky business. Success is intricately tied to exactly how acceptable firing thresholds are determined and imbedded in fully-automated STS networks. These thresholds should be dynamically adaptable to changing battlespace conditions that dictate the mode of threshold control that should be in force.

In this study, we propose to develop new guidelines for fully-automated fire/no fire STS thresholds using a framework of probabilistic Modal Logic, and evaluate this approach using both prepositional Kripke and Bayesian network models. We introduce the notion that an acceptable surrogate for enemy intent can be completely characterized using a finite set of enemy operational states (EOS). Exactly which EOS the battlespace is in, or will be in the near future, can be probabilistically determined using the magnitude of associated key descriptors (KD) whose levels are directly affected by sensor information input. Because knowledge of an EOS directly conveys enemy intent, the results of this study should provide meaningful insights toward resolving outstanding information fusion issues associated with STS networks. Moreover, by determining appropriate sets of key descriptors (KD) in the fashion described, that also have a set of desirable mathematical properties, we can obtain valuable insights as to what “symptoms” of the battlespace sensors should be designed to detect. We acknowledge up-front that these might not be the traditional ones designed for sensing in the existing suites of battlespace sensors.

The underlying principle of our approach is the belief that sensor information leading to the conclusion “true” while the battlespace is in one enemy operational state (EOS) is not

necessarily “true” for a different EOS. There are degrees of state that condition truth statements in the battlespace. This means that the level of acceptable evidence concerning a potential target in one EOS can be dramatically different from that of another EOS. We therefore posit that if an STS system is to have preset levels of target acceptability thresholds, then:

- (a) these thresholds must be capable of being directly determinable from KDs whose levels are determined from pure sensor information;
- (b) the STS fire/no fire decision system must be capable of switching between control modes corresponding to different EOS; and
- (c) the target confirmation acceptability thresholds must explicitly align with the rules of engagement in force.

Scope of Work & Methodology:

We propose to study the construction of a new framework for STS networks capable of providing guidelines concerning target acceptance thresholds for fully-automated STS networks. This study will include, but is not limited to:

1. A computational and theoretical comparison of Modal Logic to other methods to reason about uncertainty in the FCS Information Fusion Framework. The comparative methods include, but are not limited to: Bayesian Belief Networks, Fuzzy Logic, and Expert Systems.
2. Using modal logic to reason about truth values at various levels of the network information flow framework. Use Modal Logic to illuminate those KD's that support other EOS's other than a dominant EOS. This might help identify deception and also selection of efficient KD sets.
3. Combining elements of graph theory and Modal Logic to help identify a potentially optimal set of key descriptors, and developing strong metrics for associating the levels of specific descriptors with specific EOS's.

Results Summary:

This study, culminating in a Masters Thesis for CPT Henderson, produced a meta-model that uses a concise set of ontological grammar and constructs for defining and fusing battlefield information. Computational test studies demonstrated its effectiveness with three functional simulation implementations using a Bayesian Belief network, a Kripke logic model, and a Fuzzy logic model. In all three cases, the meta model was successful in effectively determining the enemy operational state based on the accumulation of likelihood evidence over time.

Moreover, the much simplified information structure provided by the new meta-model greatly facilitated cross-comparison and fusing of information, thereby demonstrating a potential fallacy associated with the ‘more is better’ attitude towards gathering sensor generated data. Future extensions proposed for follow-on work intend to demonstrate the ease by which enemy deception operations can be effectively filtered out of the operational state identification process, and a computational comparison between this meta model and neural network performance.

Presentations and Publications:

- Henderson, Steven. "Intelligent information fusion in battlefield sensor networks." Masters Thesis, Department of Systems and Industrial Engineering, University of Arizona, Tucson, Arizona, 2003.

Status: On-going.

Modeling Corrosion from Eddy Current Non-destructive Tests

DSE Project No: DSE-R-03-14

Client Organization: Department of Systems and Information Engineering, University of Virginia & USAF Research Laboratories, Wright-Patterson AFB, OH

Senior Investigator: Dr. Patrick J. Driscoll, Ph.D.
Principal Analyst: MAJ John Brence, M.S.

Points of Contact:

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Donald E.Brown, PhD (PhD Advisor)	Department Chair Department of Systems and Information Engineering University of Virginia	804-982-2074	brown@virginia.edu
Ms. Deborah Peeler (Potential Client)	USAF Research Laboratorie, Wright- Patterson AFB, OH		Deborah.Peeler@wpafb.af.mil

Problem Description: (Dissertation Research for PhD in Systems Engineering)

This research involves the development and comparison of mathematical models using non-destructive test (NDT) data from eddy current (EC) scans of the United States Air Force's (USAF) KC-135 aircraft. The models are based on the relationship between artificial and natural corrosion EC responses. The response class is based on calibration specimens (artificial corrosion) and a surrogate corrosion measurement, percent material loss. The best model(s) are determined by analyzing the results of several different modeling processes.

Quicker, more effective methods of corrosion prediction and classification will help ensure an operationally ready fleet capable of conducting military operations worldwide. This is especially critical now, as the armed forces strive to meet the increased expense of repairing aging aircraft with a dwindling budget.

These budget constraints make it imperative to correctly determine the appropriate time to replace corroded parts. If the part is replaced too soon, the result is wasted resources. However, if the part is not replaced soon enough, it could possibly cause a catastrophic accident. The development of a model that limits the possibility of a costly accident while optimizing resource utilization would allow the military to efficiently focus its maintenance and budgetary efforts. This model would not only be useful to the military but could also apply to civilian aviation or other vehicles prone to corrosion damage. The goal of this research is to explore the framework of such a modeling tool.

Scope of Work and Methodology:

Robust methods are needed to model scientific data, such as NDTs. There are irregularities in the data due to scientific error, interesting occurrences, or just because nature produces results in that fashion. Robust measures are important because they avoid incorporating characteristics or structural features of the data that do not truly exist in which other modeling techniques would use to build the model. When irregularities

or outliers are present in the data, classical methods of estimation and inference, such as Least Squares or Gaussian Maximum Likelihood, are adversely affected and could lead to poor predictive models or misleading statistical inference. Robust methods are extremely useful in modeling real world data because the statistics and techniques used are resilient with respect to irregular patterned data that contain outliers and generally provide a good fit to the bulk of the data. As such, robust methods provide more stable and reliable predictive models and more stable and accurate inference models when compared to classical methods.

Summary:

Work continues with an expected completion scheduled Spring 04.

Presentations and Publications:

- Brence, John. Complexity Challenges in Modeling Corrosion: Applying Robust Measures to Random Forests for Regression, Dissertation Proposal and Presentation. 11 November 2002.

Personnel Briefed:

- Dr. Patrick Driscoll (DSE, USMA, Senior Investigator)
- Dr. Donald Brown (DSIE, UVA. Advisor)
- Dr. William Scherer (DSIE, UVA, Chair)
- Dr. Michael DeVore (DSIE, UVA, Committee Member)

Status: Ongoing.

Air Warrior-Comanche Censored Data Test Methodology

Research Project No: DSE-R-0305

Client Organization: Operational Test Command (OTC)

Principal Analyst: LTC Andrew Glen, Ph.D.
Senior Investigator: Bobbie Leon Foote, PhD.

Points of Contact:

NAME:	ADDRESS:	PHONE:	OTHER:
Col Alton McKennon	OTC, Aviation Test Directorate Ft Hood, TX	(254) 288-9992	McKennonAlton@otc.army.mil

Problem Statement:

Develop and implement into the APPL software a methodology to perform statistical tests on censored data for the purpose of testing performance of new designs for components and systems being tested by OTC.

Scope of Work & Methodology:

Theoretical investigations were carried out and a new random variable was developed and tested which greatly increased the power of censored data of type II testing. The Methodology can also be used sequentially to reduce time on test by stopping early.

Results Summary:

The new methodology was judged to be original enough and efficient enough to warrant an attempt to patent by the Director of the ORCEN. Two demonstration tests were run for OTC at Fort Hood, TX for Mr. Richard West. The patent application is in process at OJAG in Arlington, TX. Medical doctors have proposed that the methodology has important applications in testing drug therapies.

Presentations and Publications:

- Glen, Andrew and Foote, Bobbie L., "Goodness of Fit for Censored Data", Presented to the MORS Conference, Oct 16, Albuquerque, N.M., 2002.
- Foote, Bobbie Leon and Glen, Andrew G., "A Distribution Free Test Of Censored Data", Proceedings of the IERC, May 18-21, Portland, OR, 2003.
- Submitted to Biometrics LTC Glen and Professor Foote co-authors: "A Uniformity Test and an Inference Methodology for Goodness-of-Fit Lifetests with Type II Right Censoring" 7/8/03.

Personnel Briefed:

- COL William Klimack and CPT Mary Lou Hall, May-June 2002.

Status: Complete.

Analysis of Reliability When Data is Masked

DSE Project No: DSE-R-0330

Client Organization: Operations Research Center for Excellence (ORCEN),
Department of Systems Engineering, USMA, West Point, NY, 10996

Principal Analysts: Bobbie Leon Foote, Ph.D.; LTC Andrew Glen, Ph.D.
Senior Investigator: Lt. Col. Edward Pohl, Ph.D.

Problem Statement:

Instrumentation in the field is often incomplete. This means that when an item fails, we do not have information on all the system components. It is then not directly clear which component caused the failure. This research focuses on determining if the ability to find the exact distribution of the circuit using APPL, a probability computational software designed by LTC Glen, can be used to accept or reject that a given component is failing in the time interval hypothesized initially. This analysis will apply to series, parallel and series parallel type systems.

Scope of Work and Methodology:

Series – Parallel systems were created. For a given construct each component was assumed to have a unique distribution of failure time. These distributions were selected from: Exponential, Normal, Weibull, Uniform, Gamma, Beta. APPL was executed to determine if the distribution of the entire circuit could be found.

Results Summary:

For the Uniform and Exponential, Distributions of the sample systems could be obtained. However in these uniform cases (all components having the same distribution form), inferences on individual components could not be derived. For some systems with components having combinations of distributions such as Weibull and Gamma combinations, distributions of the system could be found and inferences on individual components could be determined. However, many computational problems arose as the size of the system increased and individual combinations of distributions changed. Further, when exact forms of the System probability distribution were found, functions such as WhitterkerM that formed part of the equation for the distribution were very difficult to evaluate. Significant work needs to be done to develop System probability distributions for combinations of standard component distributions and then construct the appropriate inference test.

Presentations and Publications:

- Industrial Engineering Research Conference (IERC), May 18-21, Portland , Oregon. "Estimation of Parameters for Complex Circuits Having Masked Data"

Status: Complete

Getting Back to the Basics for Tactical Communications at West Point

DSE Project No: DSE-R-0336

Client Organization: Army Department of Military Instruction (DMI), USMA – West Point

Principal Analyst: MAJ Gregory A. Lamm, M.S.

Secondary Analyst: Mr. John T. Perullo

Senior Investigator: COL William K. Klimack, Ph.D.

Point of Contact:

NAME:	ADDRESS:	PHONE:	OTHER:
CPT Tom Mc Cardell	Operations Officer, DMI	938-4371	Thomas.Mccardell@usma.edu

Problem Statement:

Communications assets and networks are deployed to provide command and control for Cadet Summer Training (CST) each and every summer. Each year several communications problems may impact the ability for the Department of Military Instruction (DMI) to monitor key events, provide emergency assistance to cadets and provide scheduling training. Overall, we must understand the communication environment and the functions that we want to accomplish during CST.

Scope of Work & Methodology:

The report outlines a rudimentary understanding of wave propagation, and communication system characteristics. All communication systems perform differently under different environments and conditions, and the knowledge helps system designers predict signal coverage and reliability, and compare performance of different signaling schemes.

CST represents a unique opportunity to model tactical and commercial radio systems. West Point's terrain is unique and posses many problems and issues for elements operating in the Area of Concern. The terrain is characterized by multiple and sharp ridgelines, rolling hills, drastic elevation changes and hilltops consisting of a heavy concentration of iron-ore deposits. CST has the added requirement to connect main post to all field-training areas, while being constrained by a small frequency block for both tactical and commercial radio systems. The frequency restrictions cause internal interference due to the proximity of the units, and diffraction and shadowing of the ridgelines. Main post's cadet area layout presents communication issues because the structures are close together, tall and made out of materials that do not propagate radio waves easily. This caused communication degradation similar to urban area degradation. West Point also has many atmospheric issues including frequent electrical storms and lightening strikes. CST also has a population of untrained users employing communication systems (e.g., cadets) which complicate training and installation issues.

We were able to model current systems after gathering data with the intent of improving the CST communication systems. The modeling consisting of path loss models, signal strength and coverage area predicted modeling. As an example, the data gathering and modeling helped generate alternative solutions that specifically improved the Very High Frequency (VHF) commercial communication area coverage for the field training areas from 75% to approximately 95%.

Results Summary:

We recommend setting up the required command posts and all assets based on the knowledge outlined in the technical report. The report covers an introduction to the problems (Chapter 1), overview of the terrain and communication system capabilities (Chapter 2), grounding issues (Chapter 3), path loss modeling (Chapter 4), interference issues (Chapter 5), antenna parameters and modeling (Chapter 6 and 7) and power line issues (Chapter 8).

Presentations and Publications:

- Lamm, Gregory, and John T. Perullo. *Getting Back to the Basics for Tactical Communications at West Point*. Technical Report No. DSE-TR-03-36, June 2003. Operations Research Center, Systems Engineering Department, West Point.

Personnel Briefed:

- CPT Thomas McCardell, Operations Officer DMI, Cadet Summer Training

Status: Complete.

Unit Manning Study

Research Project No: DSE-R-0328

Client Organization: Army G1

Principal Analyst: MAJ David Sanders, M.S.

Senior Investigator: COL Michael L. McGinnis, Ph.D.

Points of Contact:

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MG Lawrence R. Adair Deputy G-1	300 Army Pentagon Washington, DC 20310-0300	(703)-692-1585	

Problem Description:

Background. The U.S. Army mans units through an individual replacement system. The G-1, at the direction of the VCSA, has formed a Task Force to investigate the issue of "unit manning" to determine a more effective method of supplying personnel for combat units. The D/SE was initially asked to assist the task force by helping to develop a methodology for the task force to follow. Subsequently COL McGinnis was named as the Task Force Director and chartered to:

- Review the history of Army unit manning, and related efforts, and draw lessons from these efforts.
- Define, scope and bound the unit manning problem.
- Recommend alternatives for unit manning the Army to enhance unit cohesion and improve Army readiness.
- Analyze costs and policy implications of implementing a unit manning system.
- Recommend an implementation plan to transition from an individual replacement system to a unit manning system

Scope of Work & Methodology:

During this time manning concepts were researched and analyzed, Unit Manning concepts are developed, and a scheduling model that was utilized to analyze the effect of Unit Manning on the Army as a whole is discussed. Concepts and plans developed include the ways in which Unit Manning could be executed, to include the development of the pilot program, 172d SIB/SBCT 3. Papers were published and a web site developed to explain UM to the Army and to facilitate change. A scheduling model was developed that was utilized to analyze the effect of Unit Manning on the Army as a whole is discussed. Output of the model consists of a Manning and Rotation schedule that additionally supports analysis of transformation decisions, and identification of friction

points in terms of unit availability and personnel requirements. This analysis was presented to the Chief of Staff, Army, who approved concepts and the pilot unit.

Results Summary:

On May 1, 2003, the Unit Manning Task Force briefed the Army Chief of Staff, General Eric Shinseki, on unit manning feasibility and analysis of 'friction points'. The briefing was based on modeling and analysis presented in this paper. At the conclusion of the briefing, the Chief decided that the Army would go forward with unit manning; a decision that is being carried out under the new Army Chief of Staff, General Peter Schoomaker. The first unit to be manned would be 172nd Separate Infantry Brigade, Fort Wainwright, Alaska. General Shinseki and the Secretary of the Army, The Honorable Thomas E. White, jointly approved the following news release announcing this decision.

FOR IMMEDIATE RELEASE

ARMY ANNOUNCES SBCT UNIT MANNING INITIATIVE

The Army announced today that Stryker Brigade Combat Team (SBCT) Three, presently the 172d Separate Infantry Brigade, U.S. Army Alaska, will be the first Army unit manned under the Unit Manning Initiative. The Army's intent for unit manning is to improve combat readiness and cohesion while setting conditions for improved soldier and family well-being. Unit manning synchronizes the assignment of soldiers with the life cycle of their unit. This decision combines two crucial initiatives: first, transforming the Army from an individual soldier replacement system to a unit manning system that enhances cohesion, keeps trained soldiers, leaders and commanders together longer, thereby improving warfighting capability, and second, maximizing the capabilities of Army units.

Unit manning the 172d SBCT will provide the Army with an important opportunity to develop and implement evolving personnel policies tailored to both building and regenerating SBCTs. Army G-1 personnel policy officials have identified a number of personnel policies that could be improved to support unit manning and to decrease personnel turbulence. From this experience, the Army will also gain important insights for unit manning Objective Force units in support of the Army's Transformation Campaign Plan. Unit manning will enable the Army to convert current units into Objective Force units in conjunction with fielding of Future Combat Systems (FCS). The goal is a trained and ready Alaska SBCT deployable for operations from the time of its initial operating capability (IOC) in summer, 2005 and beyond.

"We are an Army at war and transforming. We must transform to be fully ready to fight and win against emerging threats and across the full spectrum of conflict. Unit manning is a part of that transformation and the Stryker Brigade Combat Teams, beginning with the 172nd, are the right units for this initiative," said Secretary of the Army Thomas White.

For more information call Army Public Affairs at 703-697-5343. -- END

This paper formulates and models a complex scheduling problem of practical interest to the United States Army; namely, scheduling unit manning in support of unit rotations and Army transformation over an extended finite planning horizon of 164 months. Modeling and analysis in support of the Unit Manning Initiative made several contributions to military operations research and to the United States Army.

- This effort documented, for the Army and the military operations research community, the mathematical formulation of the unit manning scheduling problem that, for the first time, incorporates important dynamics of unit rotations and Army transformation.

- The process of developing the scheduling model brought together disparate groups from Headquarters, Department of the Army Staff including Personnel (G1), Operations (G3), Transformation (G7), Requirements (G8), U.S. Army Human Resources Command (HRC), U.S. Army Training and Doctrine Command, U.S. Army Accessions Command, Objective Force Task Force, Personnel Transformation Task Force (PTTF). Model development created an opportunity for these organizations to work collaboratively on Army initiatives that ultimately moved the Army forward toward transformation and unit rotations.
- Model development resulted in the implementation of an automated scheduling and decision support system capable of supporting broader analyses of a wider range of scheduling problems related unit manning in support of unit rotations and Army Transformation (see below).
- The unit manning decision by the Secretary of the Army and the Chief of Staff of the Army is a key enabler for the Army to make a major paradigm shift from *Alert-Train-Deploy* to *Train -Alert -Deploy*.
- The modeling and analysis of unit manning methods, which convinced decision-makers that it was possible to unit man brigades, set conditions for the Army, and unit leaders, to achieve higher levels of *unit cohesion* forged over time among soldiers who trust and respect each other, and function together as a team under stressful, tough, realistic conditions in training and combat.

The Unit Manning Scheduling Model supports the analyses of a variety of Army installation and training program management issues, such as,

- evaluating the economic impact of different resource utilization policies;
- evaluating unit manning readiness as a function of training capacity and training program throughput for meeting future unit manning requirements;
- forecasting training resource requirements for the initial entry training program;
- improved forecasting of operational and training resource requirements; and
- more efficient resource scheduling;

In summary, sound modeling and analysis of unit manning provided senior Army leaders with confidence that a unit centric approach to building unit cohesion and high performance teams was feasible. The analysis of unit manning showed that it would be possible for the Army to synchronize the assignments of large numbers of soldiers with training and employment of (unit-manned) units; reduce unit turbulence by managing personnel gains and losses into a compressed time period; and managing force modernization and force structure changes within the unit manning concept. Without constant turnover, units in the future will be able to train to a higher standard and gain the benefits of cohesion and camaraderie which are now only enjoyed in elite units. Unit manning is the key to setting conditions for the Army to build highly cohesive, combat ready teams at brigade and below-units that bear the major responsibility for closing with and destroying the enemy under the most stressful conditions imaginable.

Presentations and Publications:

- McGinnis, Michael L.; Sanders, David M.; Nguyen, Dat; Redd, Ammon; Junko, Ben Presentation at the 2003 Systems and Information Engineering Design Symposium, *Scheduling and Readiness considerations of a Unit Manning System*, Charlottesville, VA, April, 2003
- McGinnis, Michael L. and Sanders David, M. DSE Technical Report: *Unit Manning*, June 2003
- McGinnis, Michael L. and Sanders, David M. Presentation at the Military Operations Research Society, Working Group 24 (Measures of Effectiveness): *Unit Manning System Measures of Effectiveness*, Quantico, VA, June, 2003
- McGinnis, Michael L. and Sanders, David M. Presentation at the Military Operations Research Society, Working Group 20 (Personnel): *Personnel Considerations for a Unit Manning System*, Quantico, VA, June, 2003
- McGinnis, Michael L. and Sanders, David M. Presentation at the Military Operations Research Society, Working Group 21 (Readiness): *Readiness Considerations of a Unit Manning System*, Quantico, VA, June, 2003
- McGinnis, Michael L. and Sanders, David M. Presentation at the Institute for Operations Research and Management Science (INFORMS), *Unit Manning*, Atlanta, GA, October, 2003
- McGinnis, Michael L. and Sanders, David M., Presentation at Defense Analysis Seminar XII, *Unit Manning the U.S. Army: A Paradigm Shift from Alert-Train-Deploy to Train -Alert -Deploy*, Seoul, Korea.Mar-Apr, 2004.
- McGinnis, Michael L. and Sanders, David M., Presentation at Us-Canadian OR Symposium, *Development of Unit Manning Concepts and Integration with Rotations and Army Transformation*, Ft Monroe, VA, August, 2003.

Personnel Briefed:

- January 2003: VCSA, CSA, SA briefed on UM concept.
- March 2003: SA Decision on Pilot
- April 2003: Briefing to D/G-3 & VCSA on Army wide effect of Unit manning
- May 2003: CSA Decision Brief on Army-wide Unit Manning & Unit Rotation
- May 2003: SA Decision Brief on Army-wide Unit Manning & Unit Rotation

Status: Complete.

Base Realignment and Closure (BRAC) 2005: Army Installation Military Value Analysis

DSE Project No: DSE-R-0337

Client Organization: Deputy Assistant Secretary of the Army (Infrastructure Analyses)

Senior Investigator: Dr. Gregory S. Parnell, Ph.D.
Analysts: LTC Willie McFadden, Ph.D., LTC Michael J. Kwinn, Jr., Ph.D.,
CPT John K. Harris, M.S.

Points of Contact:

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LTC William Tarantino, Chief, Modeling Support Team	Army TABS Office 1400 Key Blvd, Suite #2 Arlington, VA 22209-1518	(703) 696-9529	william.tarantino@us.army.mil

Problem Statement:

The purpose of this research project is to provide Base Realignment and Closure (BRAC) 2005 infrastructure analysis support to Dr. Craig College, Deputy Assistant Secretary of the Army (Infrastructure Analyses) and the Total Army Basing Study (TABS) Group. There have been four previous BRAC rounds in 1988, 1991, 1993 and 1995, during which defense officials picked 97 major domestic bases for closure, 55 major bases for realignment and 235 minor installations to be either closed or realigned. The BRAC 2005 round will be part of the Defense transformation effort with strong involvement of the OSD and Joint Staff. The services will develop their BRAC methodologies in 2003. The installation data call will be conducted in 2004. The BRAC Commission will be formed in 2005 to recommend realignments and closures to the SECDEF and President. We will develop and implement a methodology to assess the military value of each Army installation and the total Army infrastructure. The methodology will be documented in a technical report by December 2003.

Scope of Work & Methodology:

The following are our major research objectives:

1. Identify key BRAC infrastructure and installation transformation issues and opportunities through research and interviews with Army senior leaders.
2. Develop an objective, credible, and auditable methodology for BRAC Army infrastructure transformation analysis and installation Military Value Analysis that will support senior Army decision makers.

3. Implement the Army Military Value Assessor Model using approved decision support software.
4. Write a white paper that describes the recommended methodology to support BRAC decision making.

The methodologies we are using are stakeholder analysis, Multiple Objective Decision Analysis, and portfolio analysis using optimization.

Results Summary:

The following is our status for each objective:

1. Identify key BRAC infrastructure and installation transformation issues and opportunities through research and interviews with Army senior leaders.
 - a. We have interviewed over 30 Army senior leaders.
 - b. We have documented the findings in our draft technical report.
2. Develop an objective, credible, and auditable methodology for BRAC Army infrastructure transformation analysis and installation Military Value Analysis that will support senior Army decision makers.
 - a. The preliminary qualitative framework has been developed and approved by Dr. College.
 - b. We are vetting the framework with Army "trusted agents."
 - c. We are developing the quantitative evaluation measures and value functions for each installation Military Value criteria.
3. Implement the Army Military Value Assessor Model using approved decision support software.
 - a. We are developing the model using Logical Decisions.
4. Write a white paper that describes the recommended methodology to support BRAC decision making.
 - a. A major draft of the paper was completed in September 2003.
 - b. The paper will be complete by December 2003.

Presentations and Publications:

- A presentation is planned for INFORMS 2003, Atlanta, GA, on October 19, 2003.
- The methodology paper will be complete in December 2003.

Personnel Briefed:

- Dr. Craig College, Deputy Assistant Secretary of the Army (Infrastructure Analyses), several presentations.

Status: We will continue the research in FY04.

Establishing a Decision Support Framework for Analysis of Embedded Training

DSE Project No: DSE-TR-0304

Client Organization: PM Combat Systems, SFAE-GCS-AB-LF/MS

Senior Investigator: Lt. Col. Edward Pohl, Ph.D.

Senior Analyst: Bobbie Leon Foote, Ph.D.

Lead Analysts: LTC Scott Billie, M.S.; MAJ David Smith, M.S.;
MAJ Suzanne O. DeLong, M.S.

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Problem Statement:

Currently the Army is developing an embedded training (ET) capability for the M1A2 SEP and the M2A3 Bradley vehicles that would allow soldiers to practice precision gunner training in a simulated environment on the actual vehicle. Cost and Training Effectiveness Analysis of the embedded training capability are currently ongoing. Our desire is to build upon and expand the current efforts by using the systems engineering process to develop a decision support framework capable of supporting analysis of a broader set of embedded training issues. While the economics of embedded training are important, the risks associated with its development and use as well as its impact on the entire training and logistics infrastructure must also be considered. Some of the questions we would like to investigate using our framework include:

- a) What is the value of being able to train in the field?
- b) Does the added flexibility of training in the field outweigh any potential loss of realism?
- c) What are the risks associated with embedded training and does it reduce or increase mission risk?
- d) Does the creation of embedded training reduce the size of the training infrastructure or decrease their utilization of training centers to the point that they are no longer cost effective?
- e) Are there benefits to enlarging the scope of training in the embedded trainers? For example, is distributed simulation a worthy avenue to pursue?

Scope of work and Methodology:

The systems engineering process was employed to develop a value model that can be used to trade-off the benefits and risks associated with using embedded training for various tasks on the M1A2 SEP and the M2A3 Bradley vehicles. The framework developed, while specific to the M1A2 and M2A3 vehicles, will be flexible enough that it can be easily adjusted to analyze these same issues for the objective force and the FCS system. An appropriate value hierarchy and its associated metrics will be constructed. Multi-Attribute Utility Theory is utilized to assess the benefits and risks associated with a variety of training tasks and/or technology implementations.

A literature review of training related research was conducted and analyzed/abstracted.

Based on this review and research and developed by the ARI , an exponential model of learning and forgetting was developed and implemented to estimate the improvement in average and minimum readiness if ET is implemented and can be used after deployment.

A year long cadet capstone was initiated and executed to collect data, make observations and build a value model. The cadets interacted with researchers and stakeholders to build qualitative and quantitative data to develop the corrections to the value models.

Researchers visited armor companies and collected survey data, observed prototype ET systems and recorded anecdotal data. Reports were immediately disseminated and incorporated in modeling. Both the value model and the learning and forgetting model were implemented in excel.

Results Summary:

The research findings and conclusions show that the proposed embedded training program for sustainment gunnery training is addressing the key functional objectives, is based on sound learning principles and has the potential to be a high impact program for the Army. As embedded training alternatives are developed and assessed according to the functions, measures and criteria recommended here, some additional work needs should be accomplished.

First, an expanded user benefits study should be accomplished. The sample size needs to be increased in order to attain statistically valid results. In this study two units should be evaluated during their gunnery cycle. One unit trains solely with the stand alone trainer, another unit trains with an embedded trainer and the stand-alone trainer. The two units performance during the gunnery cycle could them be compared. Another experiment should examine unit performance for units that are deployed. One unit conducts gunnery training in accordance with unit standard operating procedures while deployed, another unit deploys with an embedded trainer. The two units are then surveyed and their performance assessed.

Second, a detailed life cycle cost assessment should be performed. This cost assessment should expand upon the basic cost assessment performed by the cadets in Appendix I by examining the costs associated with installing, maintaining, and operating the embedded trainers. This assessment must consider the effects of the trainer on the weapon systems reliability and availability. This assessment should explore the costs associated with a variety of fielding options for the embedded trainers.

Third, it is necessary to validate and tune the parameters of the learning and forgetting models established in Chapter 4. This requires that a statistically valid experiment be designed and conducted using soldiers in the field. This would require experiments in which soldiers are trained on the stand alone trainers, embedded trainers and the actual weapon system. The experiment should be designed such that we could measure the levels of learning attained through the use of the individual trainers. The forgetting curve must be validated as well. Soldiers competence at each of the various task levels should be measured after specific periods of time (weeks, or months) to measure the rates at which forgetting occurs for the specific tasks.

Fourth, once the learning and forgetting parameters are validated, a model should be developed that sequences training over time in order to maintain a specified readiness level. This will allow decision makers to trade-off quantities of trainers and training schedules against desired unit training readiness levels.

Finally, the decision support tool should be updated and validated with input from the training IPT's and key decision makers. Additionally, the framework can be modified and utilized to assess potential technology leverage for the Future Combat Systems Program. The basic decision support framework can be updated and modified to reflect the functions, and objectives associated with embedded training requirements for FCS. Once accomplished, the decision support framework could be utilized to assess candidate technologies and approaches for implementation of embedded training on the Future Combat Systems.

Presentations and Publications:

- Computing Retention and Reacquisition Times for M1A2 Table VIII Tank Crew Level Gunnery Skills prepared by MAJ Suzanne A. DeLong, M.S., and Bobbie Leon Foote, Ph.D. and submitted to the MORS journal.
- Establishing a Decision Support Framework for Analysis of Embedded Training, OPERATIONS RESEARCH CENTER OF EXCELLENCE, TECHNICAL REPORT No. DSE-TR-0304, DTIC#: ADB292656, Bobbie Leon Foote Ph.D, LTC Scott Billie, M.S., MAJ David Smith, M.S., MAJ Suzanne DeLong, M.S., Lt. Col. Edward A. Pohl, Ph.D.

Personnel Briefed:

- IPR , July 02, MAJ Conway
- IPR, Sept 02, Sylvia Rivero, George Moore and MAJ Conway
- IPR, Dec 02, Lee Green, Lee Thompson, George Moore and Sylvia Rivero
- IPR, April 03, George Moore, Lee Green and Lee Thompson
- IPR, June 03 CPT Bridges
- Cadet visit, March 03 Ft Benning, with George Moore, OASIS trainer

Status: Complete

Deployment Scheduling Analysis Tool (DSAT)

DSE Project No: DSE-R-0315

Client Organization: The Transportation Engineering Agency of the Military Traffic Management Command (MTMCTEA)

Principal Analysts: LTC Tim Trainor, Ph.D., LTC Barbra Melendez, Ph.D.
(Department of Mathematics)

Senior Investigator: LTC Tim Trainor, Ph.D.

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Problem Statement:

MTMCTEA needs fast, flexible decision support tools to use in the area of deployment planning. They perform extensive sensitivity analysis on the many parameters involved in a military deployment. These include the types of forces deployed, the transportation assets used and the ports through which forces move. Current models lack the flexibility to alter parameters and generate quickly measures of effectiveness for a deployment. MTMCTEA needs models through which a deployment scenario can be quickly modeled, parameters changed as required and a solution generated.

Scope of Work & Methodology:

Sensitivity analysis in military deployment planning is an important function given the high-dollar and long-term nature of decisions that address the nation's strategic mobility needs. To perform this, planners need fast, personal computer-based tools for scheduling the deployment of military units around the world. Through previous work in dissertation topics related to "Scheduling Military Deployments", LTCs Trainor and Melendez have worked with others and provided MTMCTEA two computerized decision support tools to perform their needed sensitivity analysis. The proposed, long-term work is basically twofold - to maintain and update these tools and to assist MTMCTEA and their clients in using these tools for deployment sensitivity analysis. The focus for FY03 was on the more robust of the two tools, the Deployment Scheduling Analysis Tool (DSAT).

The primary decision support tool is DSAT, a prototype of which was provided to MTMCTEA in March 2001. In the DSAT, a deployment of military units is formatted as a job shop scheduling problem in which items of unit equipment are jobs moving between air/seaports (factories) on planes and ships (batch processors). The jobs are scheduled for movement using an application of the Virtual Factory, a job shop scheduling system developed at North Carolina State University that is proven to solve large problems to near-optimality very quickly. The deployment problem is built through a graphic user interface which invokes the Virtual Factory scheduling procedure and then provides meaningful output in the form of reports and graphics.

Scope of work on DSAT included:

- Maintaining and upgrading the WINDOWS 2000 version of DSAT, provided to MTMCTEA in April 2002.
- Adapting the DSAT for use in MTMCTEA's support of the Objective Force Power Projection Engineering and Analysis Project for the Center for Army Analysis (CAA).
- Incorporating software enhancements identified by MTMCTEA into future versions of DSAT.
- Updating database tables to reflect future force structures that MTMCTEA could use in scenario analysis.
- Performing a validation and verification of the DSAT results against existing deployment scheduling models used by MTMC.

The methodology for performing this work was for LTC Trainor to train users of DSAT, receive their feedback for necessary upgrades, and then attempt to program the requested upgrades. Both analysts worked with MTMCTEA on extracting the needed data for updating the appropriate database tables in DSAT to make it better meet the stakeholder and user needs. LTC Melendez designed a validation and verification plan to measure the robustness of DSAT against the primary deployment scheduling model used by MTMCTEA, the Joint Flow and Analysis System for Transportation (JFAST). This validation and verification continues.

Results Summary:

During the first part of FY03, MTMCTEA experimented with the version of DSAT delivered in April 2002. The users experienced some difficulty in performing analysis due to the sequential nature in which DSAT was programmed, i.e. unless users strictly followed the instructions for use, they could experience program termination. The number of program termination errors resulted in DSAT not being very user-friendly. LTC Trainor provided upgraded, more stable versions of DSAT in March 2003, and again in July 2003 to address some of the user concerns.

Both analysts updated the DSAT database to add the latest versions of the unit and equipment configurations for the Stryker Brigade Combat Teams so MTMCTEA analysts could model deployment scenarios using this force structure. We also added several other current Army units to the database. In July 2003, MTMCTEA requested that additional future force structures be added to the database. We also updated geographic location data in the master DSAT database.

In late FY03, MTMCTEA requested support in a joint verification and validation of DSAT against the results of JFAST. Since JFAST is apparently difficult to use, MTMCTEA analysts are providing results from JFAST-run deployment scenarios that LTC Melendez is using for comparison against DSAT results. This validation and verification process is continuing as MTMCTEA has not been able to provide JFAST results on a consistent basis due to other missions.

In July 2003, MTMCTEA requested some major upgrades to DSAT in order to use it in supporting Phase III of the Army Power Projection Program Baseline Deployment Study. These upgrades exceed the programming capability, and time availability, of the analysts. Recently, we have contracted for professional programming support through USMA's Information Technology Education Division (ITED) to upgrade DSAT to MTMCTEA's requested specifications. This work is ongoing and scheduled for completion in January 2004.

Presentations and Publications:

- Hodgson, T.J., Barbra Melendez, Kristin A. Thoney, Timothy E. Trainor. *The Deployment Scheduling Analysis Tool (DSAT)*. Special Issue of Mathematical and Computer Modeling, Defense Transportation: Algorithms, Models and Applications for the 21st Century, to be published in Spring 2004.
- Hodgson, T.J., Barbra Melendez, Kristin A. Thoney, Timothy E. Trainor. *The Deployment Scheduling Analysis Tool (DSAT)*. Presentation at the 16th International Federation of Operational Research Societies Conference (IFORS 2002), July 2002.
- Hodgson, T.J., Melendez, B., Thoney, K.A., Trainor, T. and Williams, M. *The Deployment Scheduling Analysis Tool (DSAT)*. Presentation at the INFORMS Annual Meeting, October 2003.

Personnel Briefed:

- Mr. Vandiver, the Director of the Center for Army Analysis (CAA), on *The Deployment Scheduling Analysis Tool (DSAT)- Overview and Update Brief*- 13 August 2003.
- Mr. Michael Williams, Chief, Deployability Division, Military Traffic Management Command on *The Deployment Scheduling Analysis Tool (DSAT)- Overview and Update Brief* – 8 July 2003.

Status: Continuing.

The client has funded this research through FY06. Current efforts are focused on:

- Upgrading the DSAT software using contracted, professional programming support;
- Updating the DSAT database to include future force structures, e.g. Army Regional Flotillas;
- Conducting Validation and Verification of DSAT results against JFAST.

Future Combat System Unit Set Fielding

DSE Project No: DSE-R-0339

Client Organization: Army G8

Principal Analyst: MAJ David Sanders, M.S.
Senior Investigator: COL William Klimack, Ph.D.

Points of Contact:

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COL James Creighton			

Problem Statement:

The Future Combat System (FCS) will replace current force systems. FCS will be a radical departure from current unit organization and materiel. Because of this, the Army cannot field FCS with replacement of current systems with FCS counterparts. Instead FCS-equipped units will be fielded as unit sets.

Unit set fielding (USF) offers advantages but also has adverse impacts upon the Army. In March 2003, the Army G8 briefed the Army Chief of Staff on several USF courses of action (COA). GEN Shinseki provided guidance for USF and also directed G8 to have the US Military Academy Department of Systems Engineering (DSE) review the USF COAs. DSE representatives concluded that G8 had provided feasible, acceptable, and supportable COAs. However, the G8 presentation required the decision maker to trade off complex, competing objectives. DSE then assisted G8 in constructing a decision model.

Scope of Work & Methodology:

A value-focused decision analytic approach was adopted and the goals of FCS USF were decomposed until measurable evaluation measures emerged. Measurement scales were developed and relative importance elicited from an Army staff "tiger team." Uncertainties in the outcomes for evaluation measures were incorporated in the model. The model was constructed in Microsoft Excel® with the Palisade @Risk® add-in.

Results Summary:

The decision model provided the optimum COA, and assessed the robustness of the recommendation. Model output also permitted comparison of COAs by subordinate hierarchical values. Value of COAs as a function of COA cost was provided. The results provided the basis for further study by a TRADOC working group. Additional analysis may be required as information becomes available.

Presentations and Publications:

- Klimack, William. "FCS Unit Set Fielding," invited presentation, INFORMS Conference, Atlanta, GA, October 2003.
- Klimack, William. *FCS Unit Set Fielding*. Technical Report ORCEN-TR-03-39, in preparation.

Personnel Briefed:

- GEN Byrne, Commanding General, TRADOC, June 2003
- Army G8 and Tiger Team workgroup, 17 May 2003.

Status: Ongoing.

Global Combat Service Support System – Army Analytic Support: MAC vs. Intel - Platform Analysis

DSE Project No: DSE-R-0322

Client Organization: Program Manager Logistics Information Systems (PM LIS)

Principal Analyst: MAJ Patrick Magras, M.S.
Senior Investigator: COL William Klimack, Ph.D.

Points of Contact:

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COL Stephen E. Broughall, Jr.	Program Manager Logistics Information Systems Fort Lee, VA		

Problem Statement:

Program Manager Logistics Information Systems (PM LIS) is chartered with providing information technology solutions to the tactical Army for administrative and logistics functions. To provide cost savings, the maximizing the numbers of potential vendors is desirable. The US Army has adopted a Microsoft Windows-based computing environment, often referred to as being "Wintel"-based. Apple Computer Corporation has released their OS X operating system. Apple Macintosh computers running OS X are capable of being networked with Wintel machines. Further, the Macintoshes are capable of running a program called Virtual PC® (since acquired by Microsoft but originally a third-party product). This program permits running of Microsoft Windows software. Additionally, the Microsoft Office® software packages are available for the Mac. (In fact Microsoft is the world's leading producer of Mac OS software.) Additionally, OS X is Unix-based and open source code, providing an alternative philosophic approach to computer security.

This presents the opportunity for the Army to employ Mac computers within existing and proposed LANs. This offers the opportunity of cost savings through increased competition. Further, security against malicious code is provided by having multiple operating systems.

Additionally, StarOffice™, a Sun Microsystems, Inc., software package that provides functionality similar to the Microsoft (MS) Office package was evaluated as a potential frugal replacement for Office. StarOffice consists of Writer (equivalent to MS Word), Calc (equivalent to MS Excel), Impress (equivalent to MS PowerPoint), and Draw (equivalent to MS Paint).

The purpose of the study was to

- Assess the compatibility of the Macintosh Apple iBook in a normal Army information technology environment.
- Assess interoperability in USMA internal and external web environment.

- Assess office automation and connectivity capability in Army IT environment.
- Evaluate Windows interoperability through use of windows emulator.
- Test the simplicity of configuration for hardware expansion capabilities.
- Evaluate software alternatives to MS Office.

Scope of Work & Methodology:

The test consisted of an evaluation of network, software, and hardware functionality and the assessment of the ease of transition from a Windows to a Macintosh platform. In effect, this was a beta test of employing Macintosh computers and the tested software in an existing Wintel environment. Test participants were US Army officers and DA civilian personnel.

Participants were given a brief orientation to the Macintosh then required to perform a series of tasks representative of a user in a typical office environment. Users subsequently filled out a questionnaire.

Results Summary:

Macintosh OS X provides protection against viri through a non-singular system environment. Further, this operating system is an open source package, while Microsoft follows the hidden, proprietary code model. By employing software from such different security basis, the Army may, in essence, hedge its bets regarding attack by malicious code. Participants complained that navigation was challenging. This has been observed in experienced Mac users on migrating from OS IX. OS upgrades were extremely difficult to implement, and were very time consuming for the IT staff. In fact, they relied heavily on contractors provided through PM LIS to complete upgrades.

The Mac laptops themselves worked well out of the box. They appeared robust and well designed. Anecdotal reports from Iraq suggest that Macs held up better in a field environment than Wintel machines. A limitation was that the CD burner would create a disk initially, but then no additional files could be added, unlike Wintel CD burners.

Virtual PC did permit running of Windows OS software on Macs. Virtual PC installation was not intuitive. Virtual PC operated MS products well, however the Frontline Systems Solver® add in for Excel operated slowly. This package is commonly used by Functional Area 49, operations research/systems analysis officers.

Other observations included that StuffIt Expander (the compression software provided by Apple) worked acceptably to expand/compress WinZip files. With respect to connectivity, subjects were able to connect to the LAN by Ethernet connection and via dial up. Identification of LAN servers was problematic. The Apple Airport wireless access points worked well. No parallel port is proved with the Mac. Likely this is because Apple has a proprietary FireWire cable. Disks burned on Mac (once only) could be read by Wintel machines but the reverse not true.

StarOffice™. Furnished documentation is marginally adequate. This includes the online help feature, where the index lacks obvious entries. Installation on a MS XP operating system was straight forward. StarOffice Writer is generally equivalent to MS Word. The

graphic user interface is similar, although with a slightly different feel. An experienced MS Word user may essentially begin using StarOffice Writer with only a slight drop in productivity for a short period. The online help feature appears generally sufficient for the transition. StarOffice Writer has a proprietary format, but will open and save files in the MS Word .doc format. StarOffice Writer handles equations differently than Microsoft (MS) Word's Equation Editor, which may be problematic for technical users. StarOffice does appear to fully support the Microsoft Office Clipboard. StarOffice Writer properly opened all tested MS Word doc files, including some large files. The default file format is an XML-based StarOffice Write 6 format with a "doc" extension.

StarOffice Impress was able to open and manipulate the slides. Saving in the StarOffice format prevented PowerPoint from subsequently opening the file. This means that if used, care would have to be taken to save files not as the default but as PowerPoint files. The file extension, ppt, is the same for both formats. This is potentially very problematic when trying to share information, particularly as PowerPoint briefings have become the de facto method of rapid information exchange in some headquarters. The feel again differed from the MS counterpart, but Impress seems to provide roughly the same functionality as PowerPoint.

StarOffice Calc was able to open large, complicated MS Excel files. Hyperlinks performed properly. Calc uses "StarOffice Basic" rather than the VBA used by Excel, and Excel macros did not seem to be imported. Basic functions seemed to be as in Excel. As an analytical tool, many add-ins developed for Excel, such as @Risk or Crystal Ball, are unavailable for Calc. Until these products become available, Calc is limited for high-end modeling. Calc allows macros to be written, but does not have the useful Excel capability of recording macros. Unlike Excel, Calc does not permit drag and drop of data points within a graph, a useful analytic feature.

In conclusion, Macintosh computers can be used in Army units, but a training and logistical burden is imposed. If the Army will field Macs a component of GCSS-A or in some other large program, more detailed testing is recommended to assess the training costs. Adoption should be predicated on whether savings accrued by fielding Macs exceeds these increased training and logistical costs. Virtual PC works well enough for most non-technical users, providing the ability to run current software. StarOffice provides an inexpensive alternative for Microsoft Office software.

Presentations and Publications:

- Klimack, William. "Taking a Bite of the Apple: Jaguar OS in a Wintel World," invited presentation, INFORMS Conference, Atlanta, GA, October 2003.
- Klimack, William. *Alternative PC Hardware and Software Options for Army Units*. Technical Report ORCEN-TR-03-22, in preparation.

Personnel Briefed:

- COL Stephen Broughall, PM LIS, August 2003.

Status: Complete.

Evaluating the Effectiveness of Interactive Multimedia Instruction for Soldier Tactical Mission Systems

DSE Project No: DSE-R-0320

Client Organization: PM Soldier Systems

Principal Analyst: MAJ Christopher Farrell, B.S.
Senior Investigator: COL William Klimack, Ph.D.

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Problem Statement:

PM Soldier Systems has an interest in the employment of emerging technologies to supplement traditional classroom instruction to increase the efficiency of New Equipment Training (NET). Increased efficiency would shorten NET, or permit a higher level of training given fixed NET assets. Interactive Multimedia Instruction (IMI) provides a way to reinforce learning and to evaluate soldier proficiency. IMI is generally presented in a web browser environment and provides feedback to assist learning. IMI is a strong candidate for distance learning (DL) as well.

The Operations Research Center of Excellence (ORCEN) and the Department of Military Instruction (DMI) at USMA collaborated in design and execution of this study of the utility of web-based instruction in military science education at the Academy. The first-year military science course, MS102 – Ground Maneuver Warfare I, was identified as the test bed for the DL pilot.

Scope of Work & Methodology:

In order to gauge the effectiveness of IMI in the DL pilot, courseware was required. The ORCEN and DMI utilized contracting support and other resources afforded by PM-Soldier Systems to have applicable IMI courseware storyboarded and built to the Academy's specifications. It was decided that the IMI should supplement the existing materials for a specific portion of the course. Hence, the IMI would strictly include the tasks that support map reading and land navigation as covered over several lesson blocks. Specifically, the lessons covered by the IMI included (1) Maps and their Properties, (2) Operational Terms and Symbols, (3) Terrain Features, Elevation and Distance, and (4) Azimuth and Direction.

Some existing IMI courseware was utilized as the foundation for the DL program of instruction. A crosswalk of this courseware with the Student Performance Objectives (SPOs) was conducted for each lesson. Where appropriate, the courseware was modified and expanded accordingly to insure complete coverage of all MS102 SPOs for map reading and land navigation. The resulting tasks were presented in three corresponding IMI modules. They were (1) Maps and their Properties, (2) Operational Terms and Graphics, and (3) Determine Azimuth.

In order to establish a baseline against which to test IMI effectiveness, cadets fell into one of three groups for each lesson module – control group, level 2 IMI, and level 3 IMI. Level 2 IMI is characterized by a two-way instructional flow in which the interactive courseware prompts the student to respond to lesson cues. Level 2 IMI has medium simulation presentation within which basic branching is allowed, and student responses are tracked for branching decisions as well as performance (e.g. pass/fail scenario). The training taxonomy is in the cognitive domain using the advanced knowledge category of exercise solving. This differs from the rote learning seen in level 1 IMI. In that case, the student learns largely through memorization and restatement of the material.

Level 3 IMI has essentially a one-way instructional flow commensurate with that of level 1 IMI. However, in level 3, it is in the opposite direction – student to courseware. The IMI does very little prompting but rather provides information that the student will later apply to solve a problem. It has high simulation presentation and involves the recall of more complex information than the previous two IMI levels. The user also has an increased level of control over the courseware. Level 4 IMI has real-time or *full* (virtual) simulation. The instructional flow is essentially one-way, in the same direction as that of the level 3 IMI. However, the interactive courseware does no prompting whatsoever. Errors can be compounded, and feedback and remediation are not given in the middle of the lesson – only at the end.

“America’s Army” is a government-off-the-shelf (GOTS) product conceived and managed by the Office of Economic and Manpower Analysis (OEMA) at USMA. The original purpose of the software was to improve recruiting by educating the youth of America on the various aspects of being a soldier. This includes various aspects of training, such as entry level (basic training) and Airborne school at Fort Benning, Georgia, to name a few. Over the course of a given person’s progression through the various stages of the game, certain skills and capabilities are achieved. This translates to a virtual soldier’s combat effectiveness when he or she is engaged in force-on-force exercises.

The ORCEN and DMI were the catalysts behind the first use of “America’s Army” as a training tool for individual and collective training. This was accomplished through collaboration with both OEMA and directly with the development team for software modifications. Specifically, a virtual land navigation course in “America’s Army” was created for USMA. The goal for this specific scenario was that it would serve as a practical exercise vehicle by which the fourth class cadets could be evaluated in their land navigation proficiency prior to doing it for record during Cadet Field Training in their second summer. Statistical analyses were accomplished on cadet performance scores in web-based pre- and post-tests and on elapsed times – both aggregate and between points – on the “America’s Army” land navigation course.

Results Summary:

The levels 2 and 3 IMI courseware directly contributed to improved cadet performance on the lesson post-tests for Basic Map Reading, Operational Terms and Graphics, and Determine Azimuth classes. For Basic Map Reading and Determine Azimuth classes, level 2 IMI was proven to produce better post-test results than the level 3 courseware. However cadets exposed to level 3 IMI achieved significantly better scores (times) in the virtual land navigation course than those who were shown level 2 IMI materials.

The introduction of IMI into the military science curriculum at USMA via a distance learning pilot program was a success. This study showed that, in terms of improving cadet performance in standardized, on-line tests and practical exercises that relate to map reading and land navigation, IMI is effective in achieving positive, tangible results. The desired end state is that the Army will receive the next generation of commissioned officers that are at least as proficient in land navigation skills as those in previous years. A valuable second-order benefit, however, is that they will have been exposed to simulation at various levels to conduct not only individual task training, but also collective training in both dismounted and mounted operations. In an era of extending training dollars and "doing more with less," simulation is being employed at increasing levels, not only in the Army but also across the Department of Defense and in the American workplace, at-large.

Presentations and Publications:

- Farrell, Christopher M. Memorandum Report: *Evaluating the Effectiveness of Interactive Multimedia Instruction for Soldier Tactical Mission Systems*. Operations Research Center of Excellence, United States Military Academy, West Point, NY, April, 2003.
- Farrell, Christopher M. *Experimenting with Interactive Multimedia Instruction for Military Science Education*. Presentation at the Institute for Operations Research and the Management Science (INFORMS) Annual Meeting, Atlanta, GA, October, 2003.
- Farrell, Christopher M. *Employing Interactive Multimedia Instruction in Military Science Education at the U.S. Military Academy*. Presentation at the 25th Interservice/Industry Training, Simulation and Education Conference, Orlando, FL, December, 2003.
- Farrell, Christopher M., William K. Klimack and Carl Jacquet. *Employing Interactive Multimedia Instruction in Military Science Education at the U.S. Military Academy*. Proceedings of the 25th Interservice/Industry Training, Simulation and Education Conference, Orlando, FL, December, 2003.
- Farrell, Christopher M. Technical Report: *An Effectiveness Study of Interactive Multimedia Instruction with Simulation in a Distance Learning Framework*. Department of Systems Engineering, United States Military Academy, West Point, NY, 2004 (TR in manuscript format - Pending).

Personnel Briefed:

- Mr. Ron Offutt (Program Director, Distance Learning Branch, Alion Science & Technology) – *IPR on MS102 Courseware Development*, October, 2002.
- Mr. Ron Offutt (Program Director, Distance Learning Branch, Alion Science & Technology) – *IPR for MS102 IMI Storyboard Approval*, November, 2002.
- Brigadier General Leo Brooks (Commandant, United States Corps of Cadets) - *Distance Learning Concept for MS102 – Ground Maneuver Warfare I*, December, 2002.
- Mr. Ron Offutt (Program Director, Distance Learning Branch, Alion Science & Technology) – *IPR on MS102 Distance Learning Pilot Data Reduction & Analysis*, April, 2003.
- BG Moran, PEO Soldier, May 2003.

Status: Complete.

Small Aircraft Transportation System (SATS): Airspace Infrastructure Modeling and Simulation

Research Project No: DSE-R-0323

Client Organization: General Aviation Program Office, NASA/Langley Research Center, Hampton, VA

Principal Analyst: MAJ Christopher M. Farrell
Senior Investigator: COL William K. Klimack

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Dr. Brent D. Bowen Director and Regents Distinguished Professor, Aviation Institute Department of Public Administration, College of Public Affairs and Community Service Director-Nebraska NASA Space Grant and EPSCoR Programs	422 Allwine Hall 6001 Dodge Street University of Nebraska at Omaha Omaha, NE 68182-0508	402-554-3424	unoai@unomaha.edu Fax: 402.554.3781

Problem Statement:

The proposed research will address several key SATS issues with respect to midair conflicts using widely accepted modeling and optimization techniques. The *SATS Cluster* will be introduced as the fundamental building block of state and regional SATS networks nationwide. The SATS cluster will support the National Aeronautics & Space Administration (NASA) SATS initiative as part of the National General Aviation Roadmap of the 21st Century. Previous research by the principle analyst established the degree to which the incidence of en route midair (blind) conflicts can be expected to rise as air traffic volumes increase exponentially with SATS implementation. The current research will examine various mathematical applications which will aid in future modeling of the SATS cluster.

Scope of Work & Methodology:

This research will include expansion of an existing modeling and simulation methodology previously developed by the principal analyst. This framework is centered on the creation of a test bed for SATS in the Commonwealth of Virginia and bordering states, using the SATS cluster concept developed by the principal analyst. A methodology by which to model SATS clusters will be explored. Mathematical techniques include the examination of graph theory in a bottom-up approach to modeling SATS clusters. Additionally, a mixed integer linear program (MILP) will be developed to optimize network performance among cities serviced by SATS aircraft.

In terms of the national transportation strategy, SATS is a promising alternative to current commercial air travel. The landscape of air travel as we once knew it in this country has changed forever since the terrorist attacks on September 11, 2001. The SATS initiative promises to be a bona fide factor in the future as people seek greater convenience and security with respect to their air travel options. The body of knowledge is lacking in research associated with midair conflict risk assessment and mitigation as it applies to SATS. SATS research is ongoing in several key areas. However, these are primarily concerned with determining socio-economic viability and developing revolutionary aviation technologies including onboard avionics, airport communications & weather-reporting systems, airframe and power plant design, and airborne internet protocol, among others. The airspace deconfliction challenge posed by SATS is formidable, and successful resolution is paramount to the realization of this concept. This research area needs to be exploited in the short term if SATS is to reach maturity by 2015, the FAA's stated goal.

The applicability of this research to the Department of Defense is best seen in the parallels that can be drawn between SATS vehicles and future joint service aircraft. One of the cornerstones of SATS is reliance upon advanced technologies for onboard navigation and conflict resolution. This reduces the role of air traffic controllers in en route and terminal area handling. Future military aircraft, both in the Army and in our sister services, will be heavily dependent on digital communications and navigation, with a goal of making tactical aircraft as stealthy as possible. Airspace procedures developed to control commercial "smart" vehicles can be adapted to a tactical environment containing purely military aircraft, as well as joint civil-military aviation operations during peacetime in the National Airspace System (NAS).

Results Summary:

Using the fundamental principles of graph theory, a generic SATS cluster was developed. It utilized nodes to represent SATS compliant airports and arcs for point-to-point, unidirectional air routes between SATS airports in city OD (origin-destination) pairs. Matrix representations for networks of rank, L , were generated. These matrices contained field values for the number of "walks" of length, L , between airport of origin in city i and destination airport in city j . This model was expanded in concept to cover a given SATS region in a manner similar to that of an individual cluster, with the larger graph containing nodes representing a number of individual SATS clusters.

For the optimization piece, the goal was to develop a MILP to minimize the aggregate distance flown by all SATS aircraft within the modeled region per unit time. The size of

the modeled region was limited by Microsoft Excel®'s capabilities at two SATS clusters. The model contains three of the twelve total SATS clusters in the *Virginia SATS Region* developed in previous research. Although this region is comparatively small with respect to the clusters already defined in the region, useful inferences can be drawn from the results of this problem. The eventual implementation of a national SATS strategy will likely include several SATS regions, each with numerous SATS clusters made up of SATS-compliant airports. Our modeling architecture and optimization methodology show promise even when considering problems this macro in scope. We analyzed three very busy SATS clusters in the area of Virginia and were able to minimize the aggregate distance flown between cluster pairs while simultaneously meeting the projected demand. Not only did this yield useful insights into the relative traffic between potential SATS clusters, but it also contributed to the framework for future research that can be accomplished by looking at all the clusters in the region with a more high-powered mathematical program, thus realistically modeling a *SATS region* and optimizing its performance.

Presentations and Publications:

- Loyd, Brian W. *A Graph Theoretic Approach to Modeling the Small Aircraft Transportation System (SATS)*. Presentation at the Service Academy Student Mathematics Conference, U.S. Naval Academy, Annapolis, MD, April, 2002.
- Loyd, Brian W., Farrell, Christopher M. *The Small Aircraft Transportation System: Modeling the Future of Air Travel with Graph Theory*. USMA Transactions on Cadet Mathematical Research, Department of Mathematical Sciences, U.S. Military Academy, West Point, NY, 2002.
- McConnell, Dan J., Jr. *A Mixed Integer Linear Program for Modeling the Small Aircraft Transportation System*. Presentation at the Service Academy Student Mathematics Conference, U.S. Air Force Academy, Colorado Springs, CO, April, 2003.
- McConnell, Dan J., Jr., Farrell, Christopher M. *Optimizing Performance of the Small Aircraft Transportation System*. USMA Transactions on Cadet Mathematical Research, Department of Mathematical Sciences, U.S. Military Academy, West Point, NY, 2003.

Personnel Briefed:

- Dr. Bruce J. Holmes (Director, General Aviation Program Office, NASA-Langley Research Center, Hampton, VA) – *SATS Program Update*, August, 2002.
- Research Team (FAA William J. Hughes Technical Research Center, Atlantic City, NJ) – *SATS Simulation and the Target Generation Facility*, May, 2003.
- Dr. Antonio A. Trani (Associate Professor and Program Area Coordinator, Transportation Infrastructure & Systems Engineering, Department of Civil & Environmental Engineering, Virginia Tech, Blacksburg, VA) – *SATS Research Update*, November, 2003.

Status: Ongoing.

Bradley Gun Medium Caliber Cannon Design

DSE Project No: DSE-R-0316

Client Organization: The Program Manager-Ground Combat Systems (PM-GCS)

Principal Analyst: MAJ Richard Petitt M.S., MAJ Suzanne DeLong M.S.
LTC (P) Rocky Gay Ph.D.

Senior Investigator: COL William Klimack, Ph.D

Points of Contact:

NAME:	ADDRESS:	PHONE:	OTHER:
COL Curtis McCoy	PM-Ground Combat Systems Warren, Michigan	(586)574-6630	curtis.mccoy@us.army.mil

Problem Statement:

The U.S. Army must determine the optimum main gun for the Bradley Fighting Vehicle System through the year 2032. The gun provides lethality for the system and bore diameter is particularly important for chemical energy warheads. However, larger gun calibers reduce the capacity to store ammunition and in general have slower rates of fire. Changing the present gun system also increases costs. Given these factors, an optimum gun system will be recommended based on existing candidate systems. System lethality requires that targets can be acquired, identified, engaged, and suppressed or destroyed with appropriate feedback. Areas requiring continuing research and study include: various mission profiles and environments, acquisition mechanisms, gun caliber and rate of fire, target effects and range, ammunition types and technological risks, among many others.

Scope of Work & Methodology:

The problem and basic needs of the stakeholders and users (the U.S. Army soldier) need to be identified and evaluated. This step includes communication of needs with Ft. Benning and analyzing the studies conducted by other organizations such as the PM-TMAS (Picatinny Arsenal) and the study conducted by the USMC for their AAAV (now EFV). Combat simulation scenarios need to be created, validated and verified. These scenarios should be in a desert, urban and wooded environments. Cost factors need to be identified, as well as logistical impacts incurred with the new cannon. Once combat simulations are made, statistical analysis will permit identification of any significant impacts of the alternatives in a combat environment. In addition, the logistical footprint of the cannons will be evaluated.

PHASE I – Identify the basic needs and problem definition. NOV 02

PHASE IIa – Theoretical approach to alternative and scenario generation DEC 02–JAN 03

PHASE IIb – Plan for the design process, form cadet team, develop tasks, schedule project. NOV 02 – JAN 03

PHASE III – Analyze theoretical results. MAY 03

PHASE IV – Develop practical application. JUN 2003-JUL 03

PHASE V – Develop and evaluate solution concepts. JUL - DEC 03

PHASE VI – Present findings FEB 03. Publish Technical report. MAY 04

It is anticipated that the initial concept will be evaluated using theoretical systems modeled using Combat Simulation software such as Janus or JCATS and analyzed using statistical software. A screening experiment will first be accomplished in order to eliminate insignificant factors. A practical analysis will ensue with cadet design teams using the theoretical approach applied to realistic systems.

Results Summary:

Systems Engineering problem definition and research of the current problem was conducted. MAJ Petitt travel to Aberdeen Proving Grounds and observed the medium caliber cannons in live fire testing. In addition, he traveled to Picatinny Arsenal, NJ and received a classified briefing on the current status of the project with PM-TMAS.

Additionally, Department of Systems Engineering officers met with the authors of studies conducted by Altarum (Ann Arbor, Mi.) and Burdeshaw Associates (Bethesda, Md. and sponsored by the CTAI 40mm manufacturers). The problem definition phase was completed and a draft experimental simulation design was conducted in Janus to test the unclassified results and scenarios. Classified data was received from AAMSA on the probability of kill (lethality) of the medium caliber cannon candidates. This data will be used to evaluate these candidate systems in combat simulations.

Presentations and Publications:

- DeLong, S., Petitt, R., Gay, R., Klimack, W. *“Increased Lethality Study for Future and Current Fighting Vehicles”* Military Operation Research Society Symposium, June 2003, Quantico, Virginia.
- Gay, R., Schott, R., Rybacki, M., Goddard, M., Whitten, N., Paine, J. *“New Generation Medium Caliber Weapons for Infantry Fighting Vehicles.”* INFORMS Annual Conference, October 2003, Atlanta, Georgia.

Personnel Briefed:

- COL Curtis McCoy (Program Manager-Ground Combat Systems (PM-GCS)
Bradley Lethality Study– 19 September, 2003

Status: Project continues throughout FY04. Study will be conducted in conjunction with a Systems Engineering Cadet Capstone. Results will be provided to PM-GCS in February, 2004.

Quantifying the Impacts of Aircraft Cannibalization

Research Project No: DSE-R-0325

Client Organization: The Logistics Institute (TLI), University of Arkansas,
Fayetteville, AR 72701

Sponsoring Agency: Air Force Research Laboratory, Human Effectiveness Directorate,
Logistics Readiness Branch, Wright Patterson AFB, Dayton Ohio

Principal Investigators: Stephen Orman, University of Arkansas
Graduate Student

Senior Investigators: C. Richard Cassady, Ph.D.,
Lt Col Edward A. Pohl, Ph.D.

Points of Contact:

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Problem Description:

Fleet aircraft maintenance involves a variety of activities that are intended to maximize the readiness of the fleet without violating budgetary constraints. One such activity is cannibalization. While cannibalization provides a short-term fix that makes one aircraft available, its long-term impacts can be significant. Because of the military's focus on fleet readiness and the expense of maintaining large component inventories, all military services rely extensively on cannibalization and consider it to be a normal part of fleet maintenance. A recent five-year study identified approximately 850,000 documented US Air Force and Navy cannibalizations, which consumed 5.3 million maintenance hours (equivalent to 500 full-time aircraft maintenance personnel). Other downsides of cannibalization include reduced morale of maintenance personnel, extended downtime periods for the cannibalized "hangar queens," and induced mechanical problems ("Cannibalization," *Air Force Magazine*, March 2002). The objectives of this project are to develop a mathematical modeling methodology for assessing the impact of cannibalization on fleet performance, identify policies for making cost-effective, dynamic cannibalization decisions, and study the impact of these policies on management of the spare parts supply chain.

Scope of Work and Methodology:

In order to fulfill the objectives of this project, a sequence of modeling and analysis activities must be completed: (1) Delineation of the aircraft fleet – An appropriate aircraft

system structure and other fleet characteristics will be defined; (2) Description of aircraft reliability – Traditional reliability and aging models will be defined for each aircraft component at an appropriate work unit code level (2 or 3 digit); (3) Description of aircraft maintainability – Repair times for components maintained on-site, lead times for components maintained at a depot, and additional maintenance hours resulting from cannibalization will be defined; (4) Specification of current cannibalization practices; (5) Development of a simulation model which captures fleet operation and maintenance (including cannibalization) – Fleet performance measures captured by the model will include measures of readiness, labor consumption and cost; (6) Development of revised cannibalization policies – Through experimentation with the simulation model, modifications to existing cannibalization practices will be explored. The impact of the existing and revised cannibalization policies on the management of the spare parts supply chain will be explored.

Summary of Results to Date:

This project is ongoing. Tasks 1 and 2 have been completed. Tasks 3, 4 and 5 have been started and are ongoing. A basic multi-echelon, discrete event simulation model has been developed for a simple system to investigate the effects of cannibalization and sparing levels on the readiness of the fleet. This model is being extended to account for the complexities associated with a typical fleet of aircraft.

Future Work:

We will use the results of our literature review and our simulation experiments to explore two avenues for improving fleet performance. First, we will explore revised policies for aircraft cannibalization. Second, we will explore revised policies for managing the spare parts supply chain. This portion of the study will require modification to the simulation model and additional experimentation. Our intention is to identify the key fleet parameters that influence the need for and impact of cannibalization so that we can make general recommendations regarding cannibalization and spares supply chain management.

Presentations and Publications:

- Orman, S., Cassady, C.R., and Pohl, E.A., "Exploring the Effects of Cannibalization on Fleet Performance", *Proceedings of the 2003 Industrial Engineering Research Conference*, Portland, OR, May 2003.
- Cassady, C.R., Orman, S., Pohl, E.A., "Exploring the Effects of Cannibalization on Fleet Performance", *2003 Institute for Operations Research and Management Science (INFORMS) Conference*, Atlanta, GA, October 2003.

Status: Ongoing, expected completion date June 2004.

Quantifying Army Transformation -- The Army Capability Model

DSE Project No: DSE-R-0311

Client Organization: HQDA, DCSOPS (DAMO-ZR)

Principal Analyst: MAJ Brian Stokes, M.S.
Senior Investigator: Dr. Gregory S. Parnell, Ph.D.

Points of Contact:

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Problem Statement:

The United States Army is transforming itself from a heavy mechanized force designed around for cold war missions to a more mobile force tailored to the demands of an asymmetric warfare involving many diverse missions, from peacekeeping to land warfare. The Army Future Force will be based on rapid mobility, information dominance, and tactical superiority.

The DCSOPS Resource Analysis and Integration Office (DAMO-ZR) is the DCSOPS' executive for prioritization of Army programs. They require an objective, credible, and traceable analytical process to assess the ability of the Army 04 POM programs to meet Army transformation objectives.

Our research objective was to develop a prototype decision support tool that would:

- Provide insights to key decision makers about the allocation of the Army's \$90B budget
- Evaluate MDEPs using guidance from The Army Plan
- Prioritize Management Decision Packages (MDEPs)

Scope of Work & Methodology:

Our research involved the following tasks:

- Develop a methodology for an objective, credible, and traceable analytical process to quantitatively assess how well the Army 04 POM programs meet the Army's transformation objectives.
- Develop and test the prototype on a sample of Army programs.
- Summarize the results of the evaluation and make recommendations for an improved process.

The methodologies we used were multiple objective decision analysis and decision support systems, and relational databases.

Results Summary:

We developed The Army Capability Model, a prototype decision support tool to assess current Army capabilities and prioritize potential Army programs based on their ability to support future Army capabilities. We used two key documents, The Army Plan (TAP) and the U.S. Army Objective Force White Paper, which identify future Army capabilities and transformation goals. Our decision support tool uses multiple objective decision analysis implemented in Microsoft Access to help DAMO-ZR evaluate Army programs. Each program is evaluated by the future Army capabilities it will provide. A prioritized list of programs is one of the key outputs. Other analysis outputs included budget vs. value plots and an efficient frontier plot.

The ability to prioritize programs is essential to the Army because it helps determine which programs provide the most value for the Army budget. Further, it will give DAMO-ZR the ability to assess the effects of potential changes to both program funding and the transformation goals. A follow-on project to improve on the prototype is being lead by COL Klimack in AY03-04.

Presentations and Publications:

- The Army Capability Model, 2003 IEEE Systems and Information Engineering Design Symposium, University of Virginia, 24-25 April, 2003. The Army Capability Model Research Project, Capstone Project Day, United States Military Academy, West Point, NY, 8 May 2003. (The presentation won first prize in the Department of Systems Engineering Decision Analysis Track.) The Army Capability Model, Military Operations Research Society Symposium, Quantico, June 10, 2003

Personnel Briefed:

- LTC Vic Badami, HQDA, DCSOPS (DAMO-ZR), May 8, 2003

Status: Research is continuing in AY03-04 with COL Klimack as Sr. Investigator.

Fleet Selective Maintenance and Aircraft Scheduling

Research Project No: DSE-R-0324

Client Organization: The Logistics Institute (TLI), University of Arkansas,
Fayetteville, AR

Sponsoring Agency: Air Force Research Laboratory, Human Effectiveness Directorate,
Logistics Readiness Branch, Wright Patterson AFB, Dayton Ohio

Principal Investigators: Kelly Schneider, University of
Arkansas, Graduate Student

Senior Investigators: C. Richard Cassady, Ph.D.
Lt Col Edward A. Pohl, Ph.D.

Points of Contact:

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Problem Description:

All military organizations depend on the reliable performance of repairable systems for the successful completion of missions. The use of mathematical modeling for the purpose of modeling repairable systems and designing optimal maintenance policies for these systems has received an extensive amount of attention in the literature.

Unfortunately, traditional studies in maintenance planning are limited in two key ways. First, they tend focus on a single system. This focus ignores the possibility that the system may be part of a fleet that shares responsibility for performing missions and resources for performing system maintenance. Second, they tend to ignore the mission profile of the system. This shortcoming prevents the modeler from considering important maintenance strategies including (1) performing maintenance during scheduled downtime, and (2) delaying maintenance to execute a critical mission. For the USAF fleet, these limitations are too severe to provide meaningful guidance relative to fleet maintenance planning. For a single aircraft, maintenance decisions should be made relative to its mission schedule. In addition, sortie scheduling decisions should be managed with considerations for aircraft maintenance. Given that the USAF fleet shares maintenance resources (spares, labor, etc.) and performs missions as a group, this integrated scheduling/maintenance planning problem can become quite complex. The objective of this project is to investigate the use of a mathematical modeling methodology for managing the dynamic, maintenance planning and sortie-scheduling problem.

Scope of Work and Methodology:

Achieving the objective of this project requires the completion of several key activities. First, we will define a hypothetical aircraft fleet. This definition will include specification of an aircraft type, the number of aircraft, the mission profile and the constrained maintenance resources. Second, we will formulate a mathematical model which integrates the aircraft assignment (given a sortie schedule) and selective maintenance decision-making problems. Note that selective maintenance refers to the process of identifying the subset of actions to perform from a set of desirable maintenance actions. Third, we will develop a solution procedure for solving the integrated problem. We will define an enumerative procedure for smaller problems and investigate the use of search-based heuristics for larger problems. Fourth, we will study the behavior of the integrated problem using extensive numerical experiments. This study should provide insights into and heuristic rules of thumb for managing the integrated problem. Finally, we will study the dynamic, integrated problem. In other words, we will consider the problem of updating aircraft assignments and maintenance decisions when the sortie schedule changes and/or we experience significant aircraft component failures.

Summary to Date:

We have developed the modeling structure necessary to study a hypothetical aircraft fleet. The aircraft type will be specified, and a corresponding reliability block diagram (RBD) will be constructed to capture the critical components comprising the aircraft. For each component, an appropriate reliability model will be defined, a model for the impact of maintenance on the component will be defined, and the resources required to perform maintenance will be specified. For the fleet, the required sortie schedule and the capacities on the maintenance resources will be quantified.

We are formulating a mathematical model which captures the following aspects of the integrated aircraft assignment and maintenance problem for each aircraft: its current status, its next maintenance plan, its next sortie. This formulation process is based on a review of the selective maintenance and integrated scheduling and maintenance planning literature.

The next phase of the project involves developing a solution procedure for solving the static problem. For smaller problems, we will utilize an enumerative strategy. For larger problems, we will explore the use of search-based heuristics. In both cases, we will study the static problem via extensive numerical examples. Our goal is to gain insight into the behavior of the static problem so that we can define and test rules of thumb for managing the integrated aircraft assignment and maintenance problem.

Future Work:

As with all decision problems, conditions governing the decisions evolve over time. So, we will next consider the dynamic, integrated problem. In other words, we will develop a strategy for updating the aircraft assignment and maintenance plan when conditions change. Condition changes include changes to an aircraft's status and/or changes to the

sortie schedule. Our strategy will include the static problem incorporated within a discrete-event simulation environment which captures these stochastic changes.

Once we have developed our static problem methodology, we will study it extensively using numerical examples. In addition, to gaining insight into the behavior of the dynamic problem, we hope to compare the performance of our integrated, dynamic methodology to the heuristic approaches used by fleet managers.

Presentations and Publications:

- Pohl, E.A., Cassady, C.R., Kwinn, M., "A Selective Maintenance Model for Serial Manufacturing Systems Involving Multiple Maintenance Actions," *Proceedings of the 17th International Conference on Production Research*, Blacksburg, VA, August, 2003.
- Pohl, E.A., Rufflin, S., Murdock, W.P., Cassady, C.R., "Mean Residual Life Analysis of Aging Systems," *2003 Industrial Engineering Research Conference*, Portland, OR, May 2003.

Status: Ongoing – Completion expected July 2004.

Installation Risk and Vulnerability Assessment

DSE Project No: DSE-R-0319

Client Organization: The Assistant Secretary of the Army for Financial Management and Comptroller – ASA (FM&C)

Principal Analyst: MAJ Patrick Magras, M.S.
Senior Investigators: LTC Timothy Trainor, Ph.D.
Dr. Patrick J. Driscoll, Ph.D.

Points of Contact:

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Problem Statement:

DoD installations are mandated to conduct vulnerability self-assessments annually and comprehensive vulnerability assessments at least once every three years. The current process used by Army installations for doing self-assessments is a decentralized process, normally paper-based, with standard yes/no-type questions similar to an Inspector General (IG) inspection. The current standard for comprehensive vulnerability assessments is characterized by external assessments conducted by teams at the Joint, Army and MACOM level. The intent of this work was to use the conceptual framework developed for the Installation Status Report (ORCEN work for the ASA FM&C 1992-1995), and the Threat and Vulnerability Risk Assessment tool (Engineering Management Cadet Capstone work for American International Group, Inc. Consultants 2002), to develop a standardized methodology for the Army to quantify risk and vulnerability assessments for its installations.

Scope of Work & Methodology:

The development of the IVAT focuses on incorporating existing vulnerability assessment processes utilized by Department of the Army Force Protection Assessment Teams (FPAT) from the Security, Force Protection and Law Enforcement Division of the Army Operations Center (AOC) (DAMO-ODL) and specifically utilizes the questions and standards established by the FORSCOM FPAT. The intent of the study is to provide a prototype system to the DAMO-ODL that demonstrates the utility of a web-based assessment tool and the potential for use as an entry point to the Vulnerability Assessment Management Program (VAMP). This prototype represents only a demonstration of a concept and requires further development and refinement based on DAMO-ODL feedback and installation-level beta testing and feedback. The methodology involved extensive research of existing systems for conducting vulnerability analysis, and coordination with DoD agencies involved with developing models related to vulnerability

analysis and force protection measures. The technical report for this project provides extensive background information on all of these efforts.

Results Summary:

The Installation Vulnerability Assessment Tool (IVAT) is a web-based decision support system that provides installation staffs with a simple means to perform installation VAs based on a common set of standards for like installations. Staffs perform VAs using a query-response system, a common set of metrics based on the type of installation and assessment areas weighted to reflect their relative importance to the installation mission. IVAT is SIPRnet-based with links to a secure database for retrieving assessment questions, capturing vulnerability assessments and providing local and global information to help in resource prioritization at the installation and MACOM level. IVAT is designed to be compatible with the Joint Staff Antiterrorism/Force Protection Enterprise Portal (ATEP), which allows for combining threat assessment updates with VAs to provide risk assessment for potential terrorism incidents and links to a common set of analytical resources and tools.

The IVAT is a prototype only and no validation or verification of results has been performed. This methodology could be adapted to several applications for vulnerability and risk analysis. This project has no clear sponsor at Army or DoD level, hence it is difficult to apply the methodology to the specific needs of a client. A copy of the draft technical report was given to the Army's Assistant Chief of Staff for Installation Management (ACSIM) for them to evaluate the IVAT methodology for potential future use.

Presentations and Publications:

- Magras, Patrick G.*; Timothy E. Trainor*. *Installation Risk and Vulnerability Assessment Tool*. Presentation at the 71st Military Operations Research Symposium (MORSS 2003), June 2003.
- Magras, Patrick G.*; Timothy E. Trainor*. *Installation Risk and Vulnerability Assessment Tool*. Presentation at the Institute for Operations Research and the Management Sciences (INFORMS) Annual Meeting, October 2003.

Status: Complete. Will consider adapting this for further use when a clear Army proponent for installation vulnerability and risk assessment is identified and can use further development of the IVAT.

Homeland Defense Crisis Response Research & Readiness Center

DSE Project No: DSE-R-0315

Client Organization: The Armaments Research & Development Center (ARDEC) at Picatinny Arsenal, NJ.

Principal Analysts: LTC Tim Trainor, Ph.D.

Senior Investigator: COL William Klimack, Ph.D.

Supporting Analysts: LTC (P) Ron Welch, Ph.D., D/C&ME, LTC (P) Darrall Henderson, Ph.D., D/MS, Dr. Frank Wattenburg, Ph.D., D/MS, Dr. Mike Matthews, Ph.D., D/BS&L, Dr. John Brockhaus, Ph.D., D/GENE, MAJ Tina Schweiss, M.S., D/SS

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Problem Statement:

In December 2002, ARDEC entered into a partnership with USMA to gain support for research efforts in the area of Homeland Defense. The principle project involved determining the requirements for a research and training center for Homeland Defense to be built at Picatinny Arsenal. The intent was to design a center in which both civilian and military emergency management organizations could conduct scenario-based training for small organizations in a controlled, urban-type setting. This would include incident command and control training in order to strengthen the capabilities of the many disparate emergency response organizations to work together in crisis response. The research focus of the Center would seek to place technologies applicable to Homeland Defense & Security tasks in the hands of potential end-users, thereby decreasing the research and development life-cycle. USMA's tasks included:

- Articulating an appropriate vision, and concept of research and training, for this Center.
- Conducting a training needs assessment of potential users in order to identify specific training requirements so the appropriate facilities are identified as part of the Center.
- Performing facility design in close coordination with DPW personnel at Picatinny, and in coordination with the training needs assessment, in order to develop a center that meets identified requirements while remaining feasible for the land and other resources available at Picatinny. (USMA was not to provide

final, approved blueprints for the facilities. An architectural and engineering firm will have to produce the final designs).

- Acquiring and using GIS and imagery products in the site layout and facility design process.
- Helping Picatinny articulate their case, including political analysis for a Center proponent, as they work the program and budget process.
- Estimating the resources required to develop and run the facility.
- Recommending training feedback and assessment system, specifically establishing "how" to develop assessment metrics for homeland defense command and control as part of the HDCRTC training process.
- Developing the training data collection and analysis system to be designed into the facilities.
- Conducting algorithm development, as required, to support the instrumentation of facilities.
- Planning of any virtual training that is designed into the Center.
- Providing continuity for research in supporting the development and assessment methodologies for training at the Center.

Scope of Work & Methodology:

The scope and methodology for this work falls into the major areas of concept development, training and research requirements determination, resource requirements estimation, facility planning and design, and support for promoting the Center idea to other governmental agencies.

- a. **Concept Development:** ARDEC wanted a Center that could meet the needs of as broad a population of emergency response organizations as possible. The Center vision was developed through background research of existing 'first responder' training centers, military training centers and the shared military experiences in training development, planning and execution of the several design team members. Also, the concept was aimed at filling the identified need for a centralized, controlled training area for Homeland Defense and Security tasks in the metropolitan New York/New Jersey area.
- b. **Requirements Determination:** Before designing the appropriate facilities and training/research plan for this Center, the design team needed to understand the requirements from the potential end-user view. The team held two sessions with different cross-sections of emergency responder organizations to capture their needs in Homeland Security training and research. This area also required research of existing training centers.
- c. **Resource Requirements Estimation:** ARDEC asked for a cost estimate to build and operate this Center. Unfortunately, ARDEC needed the estimates within the first month of the project in order to get the funding request process started. The Center facility costs were estimated based on the US Army Corps of Engineers (USACE) Design Manual for Military Operations on Urbanized Terrain (MOUT)

Training Complex. This document provided cost factors for several different types of facilities that comprise such a Center. The estimated costs for building the Center were created using the USACE manual to determine the appropriate types and sizes of facilities, and then applying local construction cost factors for Picatinny Arsenal obtained from the Director of Housing and Public Works (DHPW). The sizes and types of facilities provided in the estimate were modified based on the terrain available at Picatinny Arsenal for the Center.

- d. **Facility Planning and Design:** As discussed above, the original master plan was developed based on the USACE manual for a MOUT Training Complex. This plan was modified as we completed the requirements determination phase based on input received from potential end-users of the center. LTC Ron Welch developed an independent study course for two of his Civil Engineering cadet majors during second term of Academic Year 2003 in order to complete the master plan and provide ARDEC a layout of the Center on the specified terrain. These cadets made several trips to Picatinny Arsenal with LTCs Trainor and Welch to study the proposed Center area and discuss issues with the Picatinny DHPW representatives. The terrain selected for the Center abuts a wetlands area so several areas of the proposed Center site have environmental issues that must be mitigated, or worked around, in order to complete the construction. The Civil Engineering Majors, working with faculty help in the Department of Geography and Environmental Engineering on the environmental issues, developed computer aided design (CAD) drawings of the Center that placed all the Center facilities to scale on the terrain available, accounting for the size and environmental restrictions. The end product was a Master Plan for a research and training Center that could be used by the full spectrum of both first responder organizations, and their command and control headquarters, to train on emergency incident response for Homeland Security missions.
- e. **Support for Promoting the Center:** ARDEC needed assistance in promoting the plan for developing this Center to DoD and other governmental agencies. The Department of Social Sciences provided valuable analysis of the new Department of Homeland Security, and the implications of changing legislation, for ARDEC to use in targeting sources of potential Center sponsorship. The design team provided information papers of this analysis to ARDEC, and also assisted in presenting the Center plan to key decision makers.

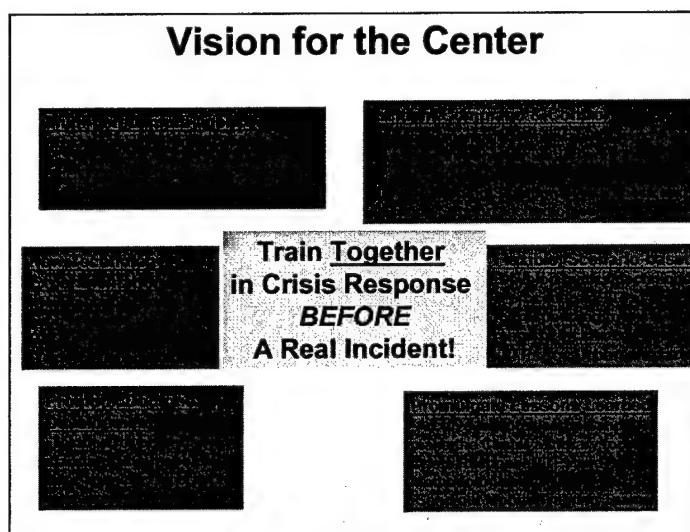
Results Summary:

The results are summarized using the same major areas breakdown provided above. Much of the results information is provided in slides and tables developed in this research.

Concept Development: The Homeland Defense Crisis Response Research and Readiness Center (HDCRRC) will allow local, state and federal agencies involved in homeland defense to conduct 'hands-on', inter-agency training with the latest technologies being developed for our military. The key focus of the center will be domestic terrorist incident response command and control training for the leadership of local, state and federal agencies in order to enhance their capabilities and interoperability. As an analog to the Army's National and Joint Readiness Training Centers, the HDCRRC

will promote doctrine development and testing for inter-agency crisis response. The center will also be a realistic test bed for new technologies, with the key potential end-users, i.e., first responder agencies, providing immediate feedback to the developers. The co-location of a homeland defense training center with a key research and development center will enable critical crisis response tactics, techniques and procedures to be developed and tested quickly. As a national center for homeland defense, the HDCRRC can archive lessons learned in testing and training and make them readily available to all agencies involved in this critical national mission.

This information is also captured in this slide:



The HDCRRC should provide a holistic training experience following the ‘crawl, walk, run’ training concept. In the ‘crawl’ phase, first responders and key agency command and control nodes will have distance learning modules available through web-based training resources. When an agency or group of agencies has requested to train at the HDCRRC, a series of pre-training conferences will identify the specific training needs and ‘home-station’ preparation necessary to make the on-site training top-notch. In the ‘walk’ mode, after specific training needs have been identified, key leaders will participate in simulation-based, or virtual reality training to better prepare them for HDCRRC training. At the HDCRRC in the ‘run’ mode, first responders will conduct hands-on training under multiple flexible and adaptable disaster and/or terrorist incident scenarios using modular, easily repairable facilities that are easy and inexpensive to maintain. Simultaneously, leadership nodes will exercise the complex interagency command and control functions that must be performed and integrated at local, state and federal level. Training facilities at the HDCRRC will be instrumented to collect data and provide feedback to users so they can adjust their tactics, techniques and procedures during training. This will also facilitate capturing and disseminating lessons learned. The slide below captures this training concept.

Training Concept

- 'Crawl':
 - **Web-based distance learning modules for 1st responders and key agency command and control nodes;**
 - **Pre-training conferences to identify the specific training needs and 'home-station' preparation necessary to make the on-site training top-notch.**
- 'Walk':
 - **Simulation-based, or virtual reality training on specified training objectives to better prepare participants them for training at the center.**
 - **Use Mobile Training Teams for specific training objectives.**
- 'Run':
 - **1st responders will conduct hands-on training under multiple flexible and adaptable disaster and/or terrorist incident scenarios using modular, easily repairable facilities that are inexpensive to maintain.**
 - **Simultaneously, leadership nodes will exercise the complex interagency command and control functions that must be performed and integrated at local, state and federal level.**

Requirements Determination: The information on the type of research and training to conduct at the Center was developed through two seminars with representatives from a broad spectrum of emergency management organizations. The following is a summary of the results of these seminars.

Maurice Schall from Picatinny Arsenal set up the first seminar with several representatives of various First Responder agencies in order to elicit their needs for training at the proposed research and training Center at Picatinny. The preponderance of participants were from law enforcement, however they represented many different functions and levels of agencies. Here is a list of the agencies represented:

Rockaway Township Police	US INS Special Response Team
Long Hill Police Dept.	Picatinny Arsenal Fire Dept.
US Postal Service	Federal Air Marshall Service
Morris County Sheriff, Bomb Squad	NJ State Police
Monmouth County Emergency Response Team (ERT) (aka SWAT)	Newark Police Dept.
Middletown Township Police Dept.	Warren County Police Dept.
	Sussex County Sheriff

LTC Trainor facilitated the seminar after the participants received a briefing on the center concept from Mr. Schall. The participants were broken down into groups by functionality (e.g. K-9/Bomb Squad, SWAT), and level of agency (e.g. local, county, state). Several different agencies were represented in each group. The groups first brainstormed and wrote answers to the following questions, not considering the impact from constrained resources (e.g. training funds, land, facilities, etc):

- What benefits could such a center provide to the mission of your organization?
- What training would your organization conduct at the Center?
- What are the key technology areas on which the Center should focus?

After completing lists for each question, the groups were asked to prioritize their training needs, the expected benefits and the technology areas of focus for the Center. After each group briefed, these were accepted as the major points for each question:

The primary benefits to First Responders from the Center will be:

- Picatinny provides a central location in northern NJ, which has a high concentration of key agencies.
- A secure, controlled and dedicated training center (these agencies experience a long, difficult setup time to conduct training in a realistic environment).
- Forum for conducting inter-agency training not accomplished now.
- Training on a wide-range of realistic scenarios.
- Location for multi-purpose live-fire training.
- Focused area for research and training in crisis response involving weapons of mass destruction (WMD) and HAZMAT; will provide a current knowledge base for tactics, techniques and procedures for counter-WMD.
- Training would be free. The agencies had the perception that they would be granted no-cost access to the resources of the Center.

NOTE: Picatinny is considering user-fee based training to pay for operation and maintenance costs. However, research to date suggests First Responder agencies do not have the money to pay for training. Any additional funds they receive in the form of FEMA or Dept of Homeland Security (DHS) grants go to fund budget gaps primarily for equipment / technology.

The primary types of training that First Responders need to conduct at the Center are:

- Weapons training, i.e. live-fire training in multiple environments. They need both outdoor and indoor range training, and a 'shoot house' for scenario-based engagements. Also, want access to bus, car and plane fuselages in which live-fire training can be conducted.
- Breaching of barriers by manual, explosive and equipment means. Barriers include doors, windows and barricades.
- Reduced visibility training, i.e. the training environment will need to permit training under conditions of reduced lighting, smoke, etc.
- HAZMAT identification, isolation, handling and removal.
- Response to incidents involving WMD.
- Incident response in schools. First Responders said school incidents present a great challenge because they do not have the opportunity to train in a school environment with long hallways, and large, separated rooms (e.g. gyms & labs). Further complicating matters is the fact that school incidents require evacuation of many people and draw immediate, large-scale public attention.
- Training that incorporates riot control agents and sound effects.
- Inter-agency coordination.

- A common point was that training needed to be video recorded for review purposes

The **primary areas for research and development** on which First Responders need the Center to focus are:

- Technologies to enhance inter-agency interoperability.
- Breaching technology and techniques.
- Personnel locators (e.g. through walls, in buildings, in rubble).
- Personnel protective equipment.
- Chemical & Biological agent detection and monitoring.
- Less-than-lethal munitions and scalable effects.
- Explosives detection.
- Situational awareness for First Responder teams, i.e. enabling team leaders/members to know where all other team members are in a confusing and/or dangerous environment.

On 28 April 2003, Picatinny Arsenal invited several members of firefighting and urban search and rescue (USAR) agencies to participate in a second seminar to define their training needs at the future Center for Homeland Defense Technologies and Security Readiness. LTC Trainor facilitated the seminar to elicit training and research requirements from the participants in order to build upon the Center master plan. Participants represented local, state and federal agencies, both full-time and volunteer organizations.

After briefing the group on the concept, vision and initial master plan for the Center, we divided the participants into four groups; City Fire Departments, Urban Search and Rescue, Fire Departments for Federal Installations, and Volunteer Fire Services. Groups were asked to brainstorm and discuss what they perceived to be the benefits from the Center to their agency, the type of training they would conduct at the Center, and the areas of technology focus for the Center. Here is the feedback elicited from each group:

USAR Group.

- Benefits:
 - Ability to conduct inter-agency, hands-on training.
 - Train on specialized scenarios & simulations.
- Training:
 - Live Agent training for WMD.
 - Canine training in USAR.
 - Training with robotics.
 - Train using USAR simulators.
 - Need a place to receive the same training as the FBI Bomb Technician School. This training needs to be certified by the FBI. The FBI school apparently has a 3-year waiting period.
- Technology: Robotics for USAR.

Volunteer Fire Service Group.

- Benefits:
 - Conduct multi-agency training at all levels.
 - Conduct advanced training scenarios beyond what they can do now.
- Training:
 - Decontamination of equipment and personnel.
 - Work in/around collapsed structures – emphasized that the structures should include utilities!
 - Mass Casualty scenarios.
 - Advanced WMD training.
 - High angle building entry.
 - Work in a radiological environment.
 - Work with Center for Disease Control (CDC) ‘push kits’.
 - Chemical detection.
 - Confined space training.
 - Advanced fire scenarios.
- Technology:
 - Interoperability of communications.
 - Information availability (i.e. situational awareness).
 - Technologies for accountability & tracking of personnel during operations.

City Fire Departments.

- Benefits:
 - Standardized training.
 - Multi-agency training is key!
 - Work on Inter-agency command and control.
 - Development of regional policies for working with other FDs.
 - Ability to configure multiple varying large-scale scenarios.
- Training:
 - Hands-on training in WMD response.
 - Hands-on HAZMAT training.
 - Collapsed building training / rubble search. Want to rubble actual buildings and then search.
 - Mass decontamination drills.
 - Hazard recognition / counter-terrorism training.
 - Training with rail/tanker car leaks and fires.
- Technology:
 - Interoperability of communications.
 - Chemical detection and monitoring.
 - Technologies for accountability & tracking of personnel during operations.
 - Decontamination methods.

Federal Agencies:

- Benefits:
 - Training in realistic and 'worst-case' scenarios.
 - Inter-agency cooperation improved – work on unified/joint command structures for incident management.
 - Ability to work with leading edge technologies.
- Training:
 - Train on incidents involving transportation commercial assets (aircraft, ships(?), subway, rail).
 - High Angle incidents.
 - WMD incidents.
 - HAZMAT scenarios (lab raids).
 - Train on the link-up between the incident command post and the EOC.
 - Water rescue.
 - Train in smoke-filled environments.
 - Search of rubble.
 - Trench collapses.

NOTE: Look at Texas A&M training center.

- Technology:
 - Burns.
 - Simulation / Virtual Reality trainers.

Here are some additional issues and concerns discussed:

- a. All agreed they needed some form of subway training platform. A potential solution is to have moveable rails that could be used to drag subway cars into an open warehouse-type facility. Temporary platforms can then be built around the cars to create the training environment.
- b. The group believed several different types of railcars are needed in the Center.
- c. The group discuss the need for a structural collapse trainer (see Texas A&M for example).
- d. Group agreed they DO NOT need a multi-million dollar burn building facility since Morris County just built one. Rather, they need a 'flashover trainer' (see Texas A&M and PA FD slides).
- e. All believed they needed to train in blackout conditions with sound effects pumped into the environment.
- f. ****Any training must be certified by the appropriate state/federal agency to make it worthwhile for civilian agencies to train.****
- g. Training should grant continuing education units (CEUs) – get a link-up with a local university for this.
- h. Local and county agencies have limited funds for training – needs to be affordable.
- i. Need to involve the NJ Division of Fire Safety and other states in the region to define training/certifications.

- j. USAR wants to do **live agent** training for WMD – this may be very difficult to conduct due to security & agent control requirements.
- k. Performing bomb technical training to FBI standards may involve significant cost and effort.
- l. Participants saw the need for aircraft fuselage fire training.

The results from both seminars is captured on the following slides:

Training Needs Assessment	
Summary of Law Enforcement / EMS Input	
<u>Perceived Benefits from such a Center:</u>	<u>Type Training to be conducted at such a Center:</u>
<ul style="list-style-type: none"> •Free (?) •Central location in northern NJ •Secure, controlled & dedicated training location •Forum for inter-agency training •Realistic training on a wide range of scenarios •'Live'-fire training •Provide a WMD training focus 	<ul style="list-style-type: none"> •Weapons; multiple forums •Breaching •Reduced visibility training •HAZMAT •School incident response •Incorporate riot control agents, sound effects •Inter-agency coordination
<u>Technology Areas of focus:</u>	
<ul style="list-style-type: none"> -Inter-agency interoperability -Personnel locators -Chem / Bio detection & monitoring -Explosive detection 	<ul style="list-style-type: none"> -Breaching -Personnel Protective Equipment -Non-lethal munitions / effects -Situational Awareness for incident 1st responders

Training Needs Assessment	
Summary of Fire Fighter / USAR Input	
<u>Perceived Benefits from such a Center:</u>	<u>Type Training to be conducted at such a Center:</u>
<ul style="list-style-type: none"> •Forum for inter-agency training •Realistic training on a wide range of scenarios •Specialized, large-scale scenario training •Work with leading edge technologies 	<ul style="list-style-type: none"> •K-9 USAR training •USAR robotics & simulator training •HAZMAT & WMD (live agent) training •Mass Casualty & decontamination •Collapsed structures w/ utilities •Inter-agency coordination •Rail/tanker/subway fires, leaks & rescues •Incident command post & EOC link •High Angle scenarios
<u>Technology Areas of focus:</u>	
<ul style="list-style-type: none"> -Robotics for USAR -Personnel locators -Chem / Bio detection & monitoring -Burn treatment 	<ul style="list-style-type: none"> -Communications interoperability -Decontamination methods -Non-lethal munitions / effects -Situational Awareness for incident 1st responders

Resource Requirements Estimation: The following section provides rough estimates for the resources required to develop and operate this Center. The facilities reflected in the tables below are an initial estimate of those required to create a center to fulfill the vision for the HDCRRC. Knowing the vision of the center is important as facilities should be built only once to serve the function designated. The tables group the facilities

into the three main functions that the HDCRRC will serve: inter-agency command and control crisis response training; first responder crisis response training that supports the inter-agency C2 training and testing of new technologies; test facilities that support research and development of crisis response related technologies.

To get to an **initial operating capability**, recommend focusing effort in FY04 on developing the facilities and infrastructure to support the inter-agency command and control crisis response training function of the HDCRRC. Table 1 provides the estimated facilities and support structure for this function of the HDCRRC.

Table 1. Startup and Annual Operating Cost Estimates to get to Recommended Initial Operating Capability

Center Support Buildings / Facilities:	Unit of Measure	Quantity	Unit Cost	Number of facilities	Estimated Cost
Classroom, Exercise Control & Emergency Operations Center Training Facility (up to 4 EOCs)	ft ²	8,000	\$165	1	\$1,320,000
Simulation Training Center (use facility on PA already)				1	\$0
HDCRTC Admin Building	ft ²	4,000	\$165	1	\$660,000
HDCRTC Supply & Maintenance Building	ft ²	4,000	\$125	1	\$500,000
Subtotal					\$2,480,000
Add 35% for Utilities, road, demolition, etc work					\$868,000
Simulation Hardware/software upgrades					\$75,000
Office Hardware, furniture					\$250,000
Total Initial Costs					\$3,673,000
Annual Operating Costs:					
Training Support Staff (one GS13 Director, one GS12 Planner, two GS11 Training Ops, 2 GS7 Training Support, all Step 5)					\$300,000
Training Overhead (20% of salaries)					\$60,000
Facility Maintenance (assume 4% of initial facility cost)					\$99,200
Utilities (assume 2% of initial facility cost)					\$73,460
Annualized Periodic Renewal (10% of initial cost every 7.5 years, growing by 10 % each renewal period out to 30 years; discount rate = 5%)					\$31,230
Total Annual Operating Costs					\$563,890

Table 2 provides the estimated facilities and structures for first responder crisis response training that will support inter-agency C² training and testing of new technologies. The first column reflects the recommended program year for developing the specified facility. A few of the facilities/structures are recommended for FY04 due to their importance and relatively low estimated cost. The ‘fire tower’ is recommended for FY04 because of the

multi-functional training opportunities it provides. Also, it should serve as the central point around which the 'downtown' building complex is developed.

Table 2. Startup and Annual Operating Cost Estimates to Develop the Structure for the First Responder Crisis Response Training

Program Year	Scenario Development Facilities: (modular, reconfigurable)	Unit of Measure	Quantity	Unit Cost	Number of facilities	Estimated Cost
	"Downtown" Building Complex:					
FY05	1 story business bldg (Strip Mall)	ft ²	3,000	\$150	5	\$2,250,000
FY05	1 story warehouse	ft ²	6,000	\$125	1	\$750,000
FY05	2 story townhouse	ft ²	7,700	\$165	1	\$1,270,500
FY05	3 story hotel	ft ²	10,000	\$165	1	\$1,650,000
FY04	Fire Tower	ft ²	8,000	\$165	1	\$1,320,000
	Residential Building Complex:					
FY05	1 story residence bldg	ft ²	1,640	\$150	5	\$1,230,000
FY05	2 story school	ft ²	8,500	\$125	1	\$1,062,500
FY05	1 story church	ft ²	4,000	\$150	1	\$600,000
	Subtotal					\$10,133,000
	Add 15% for Utilities, road, demolition, etc work (assume less work for modular training facilities)					\$1,519,950
	Subtotal					\$11,652,950
FY05	Underground Tunnel	LF	500	\$338	1	\$168,750
FY04	Aircraft Fuselage Training Facility (assume 707 fuselage is donated - cost is estimate to transport/setup)	ft ²	18,000 (footprint needed)	N/A	1	\$50,000
FY04	HAZMAT Training area (this can be done anywhere, particularly in the aircraft fuselage area; cost estimate is for equipment props)				1	\$10,000
FY04	Rubble Area (use any building demolition material or blast rock to create the area next to the business or residential complex; cost is for effects instrumentation and initial rubble setup)	ft ²	7,000		1	\$20,000
FY04	Drug Lab (can be set up in any building; cost is for prop set up and effects instrumentation)				1	\$10,000
	Total Setup Costs for these facilities					\$11,911,700
	Annual Operating Costs: (NOTE these are the additional costs when all the facilities in Table 2 are added, and do not reflect the annual operating costs reflected in Table 1)					
	Facility Maintenance (assume 4% of initial facility cost)					\$405,320
	Utilities (assume 2% of initial facility cost)					\$202,660

Program Year	Scenario Development Facilities: (modular, reconfigurable)	Unit of Measure	Quantity	Unit Cost	Number of facilities	Estimated Cost
	Annualized Periodic Renewal (10% of initial cost every 7.5 years, growing by 10 % each renewal period out to 30 years; discount rate = 5%)					\$127,601
	Total Annual Operating Costs					\$735,581

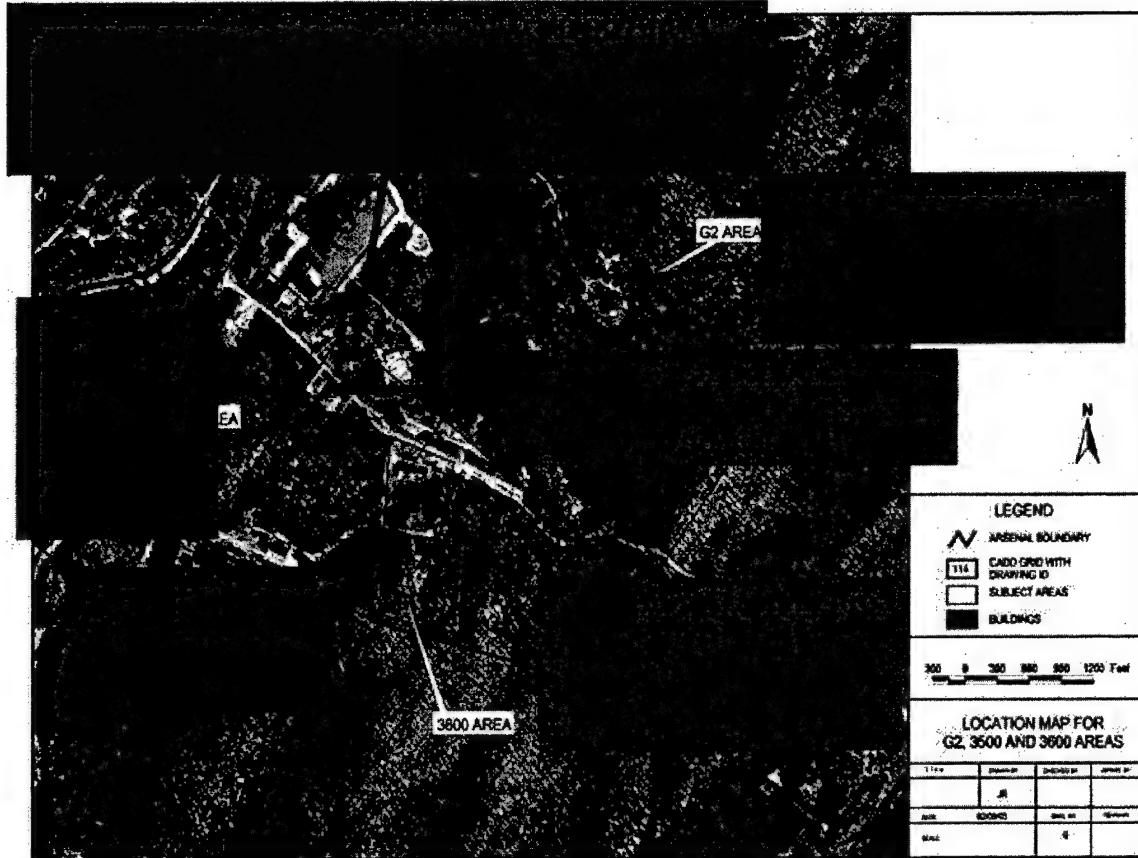
Table 3 provides the estimated facilities and support structure for supporting research and development of crisis response related technologies. The first column reflects the recommended program year for developing the specified facility. All are recommended for FY06 programming. The SWAT training facility appears to be too specific to first responder training, that is, it may not add much value to the concept of interagency command and control training, or testing of new technologies.

Table 3. Startup and Annual Operating Cost Estimates to Develop the Structure for Crisis Response Technology Testing.

Program Year	Technology Test Facilities:	Unit of Measure	Quantity	Unit Cost	Number of facilities	Estimated Cost
FY06	Human Non-Lethal Effects test facility	Ft ²	12,500	\$125	1	\$1,562,500
FY06	Robot Development testing & training facility	Ft ²	8,000	\$125	1	\$1,000,000
FY06	Information Assurance Test Facility		8,000	\$125	1	\$1,000,000
FY06	Sound Effects training facility	Ft ²	8,000	\$125	1	\$1,000,000
FY06	Small Arms Test/Training facility	Ft ²	13,500	\$50	1	\$675,000
?	SWAT Training Facility (Indoor Range)	Ft ²	5,600	\$150	1	\$840,000
	Subtotal					\$6,077,500
	Add 35% for Utilities, road, demolition, etc work					\$2,127,125
	Total Setup Costs for these facilities					\$8,204,625
	Annual Operating Costs: (NOTE these are the additional costs when all the facilities in Table 3 are added, and do not reflect the annual operating costs reflected in Tables 1&2)					
	Facility Maintenance (assume 4% of initial facility cost)					\$243,100
	Utilities (assume 2% of initial facility cost)					\$121,550
	Annualized Periodic Renewal (10% of initial cost every 7.5 years, growing by 10 % each renewal period out to 30 years; discount rate = 5%)					\$76,532
	Total Annual Operating Costs					\$441,182

Facility Planning and Design: The terrain available for the Center at Picatinny Arsenal is very limited. Wetlands issues further constrain the area available. This section above provides a list of the type and size of facilities that should comprise this Center. This section provides a few broad-scale graphics of the layout of the Center.

The slide below shows a general layout of the entire Center on the terrain available:



Picatinny Arsenal has been provided CAD drawings of each of the areas depicted above that show the layout of the Center facilities on the terrain available. Also, the wetlands areas that need to be mitigated in order to complete all facilities as designed have been identified and passed to ARDEC for action.

Support for Promoting the Center: As part of this research, USMA provided analysis of the new Department of Homeland Security and legislation changes that could assist ARDEC in gaining support for developing this Center at Picatinny Arsenal.

Additionally, LTC Trainor made a joint presentation with ARDEC representatives to Rear Admiral Crowley, USN, the Interim Director of the Homeland Security Center, on ARDEC's homeland security related efforts. The purpose of the briefing was to familiarize high-level representatives of the Department of Homeland Security (DHS) with the Picatinny's efforts and to seek partners for future development.

In March 2003, New Jersey Governor McGreevey designated Picatinny Arsenal the New Jersey Center for Homeland Defense Technologies and Security Readiness. During the designation ceremonies, LTC Trainor and COL Meese from the Department of Social

Sciences provided GOV McGreevey and Representative Rodney Frelinghuysen, 11th US District, a short brief on the continuing partnership between USMA and TACOM-ARDEC. This continuing partnership supports research and development of technology and activities that can contribute to homeland defense.

In preparation for both of these high-level events, the USMA design team provided background analysis of applicable legislation and governmental policies that ARDEC should be cognizant of during these meetings.

Presentations and Publications:

- Trainor, T. and Welch, R. *Creating a Center for Homeland Defense Research and Training*. Presented at the INFORMS Annual Meeting, October 2003.
- Welch, R. Trainor, T., Crowe, R. and Zuzulock, A. *Homeland Security Training Facility Capstone*. Proceedings of the Fall 2003 American Society for Engineering Education (ASEE) Middle Atlantic Section Conference, October 2003.

Personnel Briefed:

- Trainor, T. and Meese, M. *Picatinny Arsenal - USMA Partnership for Homeland Defense Research*. Presentation to the Honorable James E. McGreevey, Governor of New Jersey, and Congressman Rodney Frelinghuysen, 11th US District, March 2003.
- Trainor, T., et.al. *ARDEC Efforts in Homeland Defense Related Research*, presented to Rear Admiral Crowley, USN, the Interim Director of the Homeland Security Center, Washington DC, April 2003.

Status: Continuing. The client has funded this research through December 2004. After the USMA design team provided the recommended master plan for the Center, Picatinny Arsenal was notified that Military Construction (MILCON) funding would not be available in FY04 to develop the Center. ARDEC has recently teamed up with the Communications and Electronics Command (CECOM) to pursue funding for the Center from the New York/New Jersey Metropolitan Transit Authority (MTA). The MTA is responsible for all the bridges, roads, tunnels and rail networks for the metropolitan New York and New Jersey area. The MTA has identified a need for a Center such as this to train both their first responder organizations, and their management in incident command and control operations. USMA will support ARDEC by refining the Center master plan to the needs of the MTA, if the MTA agrees to and funds training at the Center.

Disposable Sensor Operational Characteristics

Research Project No: DSE-R-0335

Client Organization: Army Research Laboratory, Sensors and Electronic Devices Directorate, Army Research Laboratory

Principal Analyst: MAJ David Sanders, M.S.
Sr. Investigator: COL William K. Klimack, Ph.D.

Points of Contact:

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Problem Description:

The Objective Force will employ sensors to enhance operational capability. Disposable sensors (DS), defined as costing less than \$10 per sensor, appear to be attractive. However, disposable sensors provide reduced capability over sensors that are more expensive. This research will examine the trade offs required for disposable sensors and the operational impacts.

As the parameters of the fielded sensors is not yet known, estimated parameters will be determined in coordination with the Signal and Image Processing Division, Sensor and Electronic Device Directorate, the Army Research Laboratory. This research effort will provide an initial analysis of the benefits and drawbacks of disposable sensors, attempt to establish performance criteria, and develop methodology that may be employed in future work when sensor performance specifications have matured.

Scope of Work & Methodology:

1. Problem definition.
 - Conduct literature search to:
 - i. Establish anticipated sensor performances,
 - ii. Establish anticipated senior employment doctrine.
 - Articulate assumptions.
2. Design and Analysis
 - Develop the scenario that will be used in the analysis.
 - Model and analyze alternatives using a simulation model, specific model TBD.

3. Results

- Establish what characteristics are traded away to gain the less expensive disposable sensors.
- Determine, if possible, the relative effectiveness of employment of disposable sensors, nondisposable sensors, and mixtures of the two types.

Results Summary:

In general, the basic scenarios (without terrain) gave us some insight into what characteristics of the sensors the Army should look to develop in its sensor fields. The simple sensor model basically confirmed our general conjectures at the onset of the simulation and validated our model. The number of detections increases with more sensors and higher quality sensors with a greater sensor range. These detections increase with decreasing returns to scale, giving some insight into the sensor quantity decision..

In the trip scenario, we observed some different results. The sensor ranges for the trips didn't seem to have a large effect of the number of average detections. The trip range of the sensors and the number of the trips had the most effect. We determined that we could get an almost optimal coverage of the battlefield, while not spending the maximum amount of money by purchasing a high number of trip sensors and low number of main sensors, as long as the trip and main sensors are of high quality. Since we feel the Army has put soldier safety at a premium, this is the best way to ensure coverage of the battlefield. In essence, the number of sensors does not matter as much as the quality of the sensor employed on the ground. In the case where we only had 15 sensors (10 trip and 5 main), more detections occurred than when we had 5 trip and 25 main sensors. Thus, with half as many total sensors, we had a better detection rate. The actual cost of these trip sensors will need to be examined to see if the benefit of utilizing them outweighs the cost of production. The Army needs to scrutinize if the current sensors really need replacement because of the high cost of developing these new disposable sensors.

Sensor Placement: The observations from the placement scenarios showed that the placement of these sensors is not crucial on its own. However, there are a number of situations on the battlefield that need to be considered. Since there is not a significant difference between the placement techniques, we can use any of these techniques based on more qualitative analysis. For example, placing the sensors at the far end of the battlefield, closer to the enemy's goal destination, may result in later detections. The detections occur so close to the enemy reaching the goal, our forces may not have time to react to the sensor information. More analysis would need to be conducted to weigh these and other more subjective factors.

Future Work: After reaching the above conclusions, we made small improvements on our models and began establishing future research goals. The first thing we did to improve on our findings above was to increase the number of trip sensors to the point we could start to see diminishing returns. To do this we took our trip sensor scenario and increased the number of trip sensors we were varying. In the main effects plot below we can see that diminishing returns begin with 20 sensors. By doing further research using this new number, our above conclusions may change slightly.

Main Effects Plot - Data Means for Detections

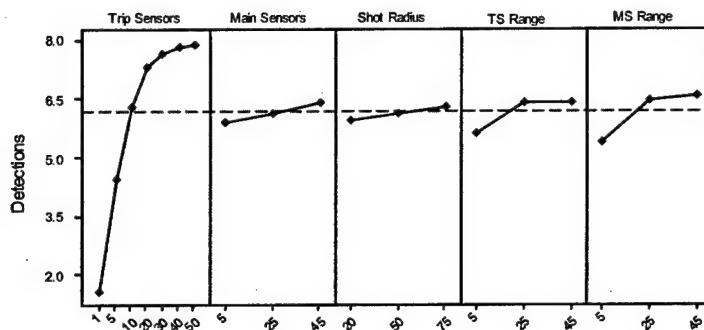


Figure 8: Main Effects for Trip Sensor Model

Other future research that we began was to try to look at a false alarm rate. The sensors would not be able to distinguish between animals and soldiers. This may be something that needs more research. The fuel rate of the disposable sensors is important. They would eventually run out of fuel depending on their level of use. At that time we may need to disperse new sensors on the battlefield. Finally, with more information from our clients, Army Research Laboratory, we would want to find out the exact type of sensors we should look at and what characteristics they have. With this information the scenarios can be changed to reflect those specific characteristics.

Presentations and Publications:

- Sanders, David M*; Klimack, William K.*, Carlton, William B.* , DSE Technical Report No. DSE-TR-03-35: *Disposable Sensor Analysis*, June 2003 – in preparation.
- Sanders, David M*; Klimack, William K.* , Carlton, William B.* , Presentation at the Military Operations Research Society, Working Group 29(Modeling and Simulation): *Land Warrior Power Management*, Quantico, VA, June, 2003
- Reese, Alaina; Rhode, Brooke; Schlanser, Matt; Sanders, David; Carlton, William. *Maneuver Warfare Science 2003* (To be published).

Status: Complete.

Methodology for the Management of Power for the Soldier Tactical Mission System

Research Project No: DSE-R-0303

Client Organization: Training and Doctrine Command (TRADOC) System Manager for the Soldier Tactical Mission System (TSM-Soldier)

Principal Analyst: MAJ David Sanders, M.S.
Sr. Investigator: COL William K. Klimack, Ph.D.

Points of Contact:

NAME:	ADDRESS:	PHONE:	OTHER:
COL Theodore Johnson Project Manager PM-Soldier Systems	10125 Kingman Rd. Room 127 Ft. Belvoir, VA 22060-5852	DSN 654-3816 (703) 704-3816 Fax (703) 704-1951	Ted.Johnson@peosoldier.nvl.army.mil
COL Walt Holton TSM-Soldier	Commander, USAIC ATTN: ATZB-S Fort Benning, GA 31905	DSN 835-1189 (706) 545-1189	Walter.Holton@benning.army.mil
MAJ Jim Smith APM-Power	PEO Soldier Ft. Belvoir, VA 22060	DSN 654-3769 (703) 704-3769	James.smith@peosoldier.nvl.army.mil

Problem Description:

The Soldier Tactical Mission System current instantiation is the Land Warrior (LW) system. Land Warrior may serve as a model for all STMSs, and the current Land Warrior version will likely be similar to the initial fielding. Regardless of evolution of STMSs, Land Warrior will be present in the inventory for some time. The PM Soldier Systems provides this description of Land Warrior (<https://www.pmsoldiersystems.army.mil/public/FAQ/default.asp#q1>):

Land Warrior (LW) is a first generation modular, integrated fighting system for the individual infantryman. The LW system includes everything the dismounted soldier wears and carries integrated into a close combat fighting system which enhances his situational awareness, lethality, and survivability. The LW System is composed of 5 integrated subsystems: Weapon Subsystem, Integrated Helmet Assembly Subsystem, Computer/Radio Subsystem (CRS), Software Subsystem, and Protective Clothing and Individual Equipment Subsystem. LW is intended for use by all five types of infantry; Ranger, Airborne, Air Assault, Light and Mechanized. LW will integrate the dismounted warfighter into the Army's digitized battlefield network.

There are 21 components to the Land Warrior system that require power. Unfortunately, current power source technology relies on batteries. Batteries are bulky and heavy so the LW soldier cannot carry a large number to power the components. Batteries only provide a power source for a limited duration, so they must be resupplied or recharged for long duration missions. Also, there is no alternate power source if the batteries are lost or damaged during a mission and resupply is not feasible.

Power management affords the greatest payoff in the soldier's power challenge. That is, the ability to efficiently manage energy utilization is achieved by incorporating adaptable hardware and "smart" software in a fully integrated soldier system architecture. The objective of power management is to use the minimum amount of power only when necessary in the most efficient manner. This objective will require closely coordinated control of all hardware and software subsystems. Future STMSs will likely demand increases in power draws and energy utilization without increasing the soldier system weight. Power management is a critical enabling technology that will enable the goals of a doubling of mission duration by 2004, and five to ten factor increase by 2008 without imposing additional weight on the soldier. These increases have been achieved in similar commercial systems, e.g., PDA's and laptop computers.

Clearly it is desirable that STMS power management receive analytical focus so that power management decisions are not required to be made expediently on the battlefield. Doctrine and information should be available to facilitate decision making by leaders of STMS-equipped units.

Scope of Work & Methodology:

The primary emphasis will be on the Land Warrior System v1.0. The proposed organization will be the squad or platoon.

4. Problem definition.

- Conduct literature searches and background studies.
- Discuss STMS power projects with other research agencies.
- Develop engineering problem statement.
- Develop value system.
- Research and document information requirements with subject matter experts. Experts include but not limited to dismounted infantry, physiological, power supply/demand, and intelligence.
- Identify critical components based on mission type.

5. Design and Analysis

- Develop the scenario vignettes that will be used in the analysis.
- Model and analyze alternatives using a simulation mode, specific model TBD.
- If possible, model and analyze alternatives using Agent Based Models, specific model TBD.
- Through interview, surveys, and/or previous research, ascertain SME opinion on the utility of the various components.

6. Decision Making

- Establish at a minimum an order of merit of system (an ordinal ranking) components by mission type/situational conditions, which determine what components are the most effective.
- Determine, if possible, the relative effectiveness of each component in relation to each other (a cardinal ranking), and utilizing that information develop an optimization model to determine what components should be on, standby, or off under what power conditions and what tactical mission/situation.

Results Summary:

This work contains the initial problem definition and modeling in support of the analysis required to develop a power management logic module. We have formulated a scenario, small in scope, and analyzed the capabilities of the Land Warrior system utilizing Agent Based Models. This technique has suggested that while ABMs can model this system the fidelity of the models does not allow us to capture component utility values. The ABMs do suggest that the highest payoffs come from the sensor and communications capabilities. Once utility values for components can be obtained from more realistic scenarios tradeoffs can be made in the selection of power usage under limited availability. This modeling is much more complex because we are not so much comparing components of the system as we are comparing possible combinations of those components, greatly expanding the state space of solutions.

Sensor range appears to have one of the most critical impacts on the system. The Daylight Video sight, the Thermal Weapon sight, and the night vision goggles all enhance the ability of the soldier to sense his surroundings. These components influence the way the soldier acts as well as his ability to affect those surroundings by immediate fires. The decisions the soldier can make are as important as his ability to range a target – in many scenarios bypassing a conflict may well provide victory, and the knowledge of enemy and friendly actions is crucial.

The way ahead for this analysis is to first further refine the scenarios in which to conduct the analysis. Today's soldiers must operate in many environments – and the measures of evaluation we wish to optimize are different between a peace-keeping operation and large scale combat, and have variations in between. Once scenarios are developed ABMs can be used to identify critical combinations of components, and higher resolution models can be used to identify specific utility values for the components and combinations of components. From these utility scores an optimization model can be developed, likely in the form of a dynamic mathematical program, which can determine which components should be used in varying situations and power conditions.

Presentations and Publications:

- Womack, Forrest; Resse, Alaina, Mcconnell, Dan; Sanders, David M; Carlton, William Presentation at the 2003 Systems and Information Engineering Design Symposium, *Land Warrior Power Management*, Charlottesville, VA, April, 2003

- Sanders, David M; Carlton, Williamv. DSE Technical Report: *Land Warrior Power Management*, June 2003
- Womack, Forrest; Resse, Alaina, Mcconnell, Dan; Sanders, David M; Carlton, William Presentation at the Military Operations Research Society, Working Group 28(Decision Analysis): *Land Warrior Power Management*, Quantico, VA, June, 2003

Personnel Briefed:

- May 2003: COL (Ret) Patrick Toffler, SY Technologies.

Status: Complete.

Modeling of Soldier Tactical Mission System (STMS) Combat Effectiveness

DSE Project No: DSE-R-0318

Client Organization: PEO Soldier

Principal Analyst: MAJ Randall R. Klingaman, M.S.
Senior Investigator: Dr. Gregory Parnell, Ph.D.

Points of Contact:

NAME:	ADDRESS:	PHONE:	OTHER:
COL Ted Johnson	PM Soldier Warrior 10125 Kingman Road Bldg 317 Ft Belvoir, VA 22060-5820	703-704-3816	ted.johnson@PEOSoldier.army.mil
MAJ Brian Cummings	PM Soldier Warrior 10125 Kingman Road Bldg 317 Ft Belvoir, VA 22060-5820	703-704-3816	brian.cummings@PEOSoldier.army.mil

Problem Statement:

The Army needs an analytic model that quantifies combat capability and survivability of an infantry squad as a function of the technology attributes of the Soldier Tactical Mission System Combat Effectiveness.

Scope of Work & Methodology:

Use complex adaptive systems theory and agent based modeling to analyze the relationships between soldier system functions in many scenarios. We will use the soldier system functions that were developed last year during another cadet capstone as a starting point. We will use the simulation information to develop an analytical model that quantifies combat capability and survivability of an infantry squad as a function of the technology attributes of the Soldier System. Specifically:

- Conduct thorough background research into the class of simulation models known as agent based models and their relevance to this project, and the development of the STMS from Land Warrior to Objective Force Warrior.
- Perform an affinity diagram with Infantry subject matter experts to determine the value hierarchy for the core functions of an infantry squad.
- Define the capabilities of three STMS alternatives and map these capabilities to the core functions of an infantry squad and then to the model parameters in the agent based simulation software MANA (Map Aware Non-Uniform Automata).
- Develop an illustrative scenario in MANA that demonstrates the combat effectiveness as technology attributes are varied.
- Develop a design of experiments to generate data and results for the two defined measures of effectiveness: average time to complete the mission and average number of casualties over time.

Results Summary:

The major findings of my research indicate that STMS alternatives can be modeled using ABMs and that technology increases can be proven in the simulation model. Disparity does exist between the capabilities and technology pieces of the STMS alternatives and the input parameters in MANA. However, enough fidelity can be achieved to warrant its use. We found that both the average time to complete the mission and the average number of casualties decreased as we increased the capabilities of the agents according to the STMS alternatives. The significant factors in both models were the firing range and firepower of the agents, which would suggest that lethality and the core function "Shoot" bear the greatest impact on combat effectiveness.

Presentations and Publications:

- Klingaman, Randall R. DSE Capstone Report: *Modeling of Soldier Tactical Mission System Combat Effectiveness*, May, 2003
- Klingaman, Randall R., Presentation at the Military Operations Research Society, Working Group 29 (Modeling and Simulation): *Modeling of Soldier Tactical Mission System Combat Effectiveness*, Quantico Marine Base, June, 2003

Personnel Briefed:

- Mr. Pat Toffler (PEO Representative from Soldier System of Excellence) *IPR and Initial Modeling Issues* – 6 March 2003
- Mr. Pat Toffler (PEO Representative from Soldier System of Excellence) *Final Results and Conclusions* – 8 May 2003

Status: Complete.

PART III - Faculty Activity, Academic Year 2002-2003

(* Indicates multiple department authors)

BELKNAP, MARGARET H., PH.D., Lieutenant Colonel

Refereed Journal Publications

Belknap, Margaret H., "The Military, The Media, and Deception," *Parameters* (Reply to Commentary), Spring 2003.

Belknap, Margaret H., "The CNN Effect: Strategic Enabler or Operational Risk?" *Parameters*, Autumn 2002.

Refereed Conference Proceedings Publications

Belknap, Margaret H.* and Daniel J. McCarthy*, "Textbook Selection: A Methodological Approach," 2003 Industrial Engineering Research Conference, May 18, 2003.

Non-Refereed Publications

Belknap, Maggie, "News as a Military Tool", *Newsday OPINION*, March 30, 2003, pp.24-25.

Conference Presentations

Belknap, Margaret H. with Joseph Galloway and Gerald Scott, "The Military and the Media: The Good, the Bad and the Ugly", Invited Panelist, Army Materiel Command Commanders' Conference, Detroit, Michigan, March 5, 2003.

Belknap, Margaret H., "Military Decision Making in the Information Age," INFORMS Annual Meeting, San Jose, California, November 18, 2002.

Professional Society Officer Positions

Chair-Elect and Program Chair, Systems Engineering Constituency Committee, American Society for Engineering Education.

Number of Refereed Journal Publications reviewed: 1.

BRENCE, JOHN R., M.S., Major

Refereed Journal Publications

Brence, John R. and Donald E. Brown, PhD. "Data Mining Corrosion from Eddy Current Non-destructive Tests." *Computers and Industrial Engineering*, 43 pp 821-840, 2002.

Non-Refereed Publications

Brence, John R. *Complexity Challenges in Modeling Corrosion: Applying Robust Measures to Random Forests for Regression*. Dissertation Proposal, University of Virginia, Department of Systems and Information Engineering, 11 NOV 2002..

BUCKINGHAM, JAMES M., P.E., PH.D., Lieutenant Colonel

Refereed Conference Proceedings Publications

Buckingham, J.M., *Do Your Students a Favor, Teach Your Faculty How to Teach*", Frontiers in Education Conference, Boston, MA, November 2002

Buckingham J.M., D. Bunt, *Imagery Enhancement to Meteorological Collection Platform*, 2003 IEEE Systems & Information Engineering Design Symposium, University of Virginia, April 2003.

Buckingham, J.M.* , D. Bunt, G. Aa. Lamm*, *Benefits of Imagery Gathering for Enhancing Intelligence Gathering*, 2003 IEEE Systems and Information Engineering Design Symposium, University of Virginia, April 2003.

Non-Refereed Publications

Buckingham, James M., David Bunt, Christopher Green, Jacob Bailey, *Imagery Enhancement to the Disposable, Air-droppable, Meteorological Tower Array (DAMTA)*, Prepared for University Partnering for Operational Support (UPOS), Army Research Laboratories (ARL), and Applied Technologies Incorporated (ATI), June 2003.

Conference Presentations

Buckingham, J.M. (Author), C. Green (Author/Presenter), *Disposable, Air-Droppable Meteorological Tower Array*, American Society of Engineering Management Conference, Tampa, FL, October 2002.

Buckingham, J.M., *Do Your Students a Favor, Teach Your Faculty How to Teach*, Frontiers in Education Conference, Boston, MA, November 2002.

Client Presentations

Buckingham, James M. "Imagery Enhancement to the DAMTA". Presented to Applied Technologies Incorporated, Longmont, CO, 18 Dec 2002.

Buckingham, James M., David Bunt, "Imagery Enhancement of the Disposable, Airdroppable, Meteorological Tower Array (DAMTA)", White Sands Missile Range, 8 April 2003.

Buckingham, James M., J. Bailey, D. Bunt, C. Green, "Imagery Enhancement of the Disposable, Airdroppable, Meteorological Tower Array (DAMTA)", Presented to Mr. Walt Hollis, DUSA, Operations Research, 5 May 2003.

BURK, ROGER C., PH.D.

Awards

Army Superior Civilian Service Medal, January 2003

Non-Refereed Publications

DeLong, Suzanne O.* , Eric S. Tollefson*, Roger C. Burk*. *Modeling of HEL Weapons in Army Combat Simulations*, D/SE Technical Report, in preparation.

Conference Presentations

Burk, Roger C., Carolina Deschapelles, Karl Doty, Jonathan E. Gayek, Thomas Gurlitz. Presentation to the International Federation of Operational Research Societies: *Performance Analysis in the Selection of Imagery Intelligence Satellites: A Case Study*, Edinburgh, Scotland, 8-12 July 2002.

Burk, Roger C., Carolina Deschapelles, Karl Doty, Jonathan E. Gayek, Thomas Gurlitz. Presentation to the Institute for Operations Research and the Management Sciences: *Performance Analysis in the Selection of Imagery Intelligence Satellites: A Case Study*, San Jose, CA, 17-20 November 2002.

Tollefson, Eric*, Suzanne O. DeLong*, and Roger C. Burk*. Presentation at the the Directed Energy Professional Society Modeling and Simulation Conference: *Modeling of HEL Weapons in Army Combat Simulations*, Albuquerque, NM, 25-27 March 2003

Presentation at the Military Operations Research Society, Working Group 10 (Unmanned Systems): *Analysis of Alternatives for an Army Extended Range Multipurpose UAV*, Marine Corps Base Quantico, VA, 10-12 June 2003

Client Presentations

Harrison, William, Thomas Karpuk, Luke Roberts, Roger C. Burk. *UAV Capstone Project Client Briefing #3*, COL John D. Burke (Program Manager, Tactical Unmanned Aerial Vehicle Systems) and MG Joseph L. Bergantz (Program Executive Officer, Aviation), 21 April 2003

Number of Refereed Journal Publications Reviewed: 4

DELONG, SUZANNE O., M.S.M., Major

Refereed Conference Proceedings Publications

DeLong, Suzanne O.* and West, Paul*. *An Undergraduate Systems Engineering Design Project For Using Constructive And Virtual Simulation For An Armed UAV Design*. Published in the proceedings of the Winter Simulation Conference, San Diego, CA, 9 – 11 December 2002.

Speegle, Clint and Suzanne O. DeLong, *Applying the Systems Methodology in the Design of the West Point Cogeneration Power Plant*, published in the proceedings of the 2003 IEEE Systems & Information Engineering Design Symposium at the University of Virginia Capstone Conference, 24 – 25 April 2003.

Conference Presentations

DeLong, Suzanne O.* and West, Paul*. *An Undergraduate Systems Engineering Design Project For Using Constructive And Virtual Simulation For An Armed UAV Design*. Winter Simulation Conference, San Diego, CA, 9 – 11 December 2002.

DeLong, Suzanne O.* , Eric Tollefson*, and Roger Burk*. *Modeling of HEL Weapons in Army Combat Simulations*. Directed Energy Professional Society Modeling and Simulation Conference, Albuquerque, New Mexico, 25 – 27 March 2003.

DeLong, Suzanne O.* , Rick Petitt*, and Rocky Gay*. *Increased Lethality Study for Future & Current Infantry Fighting Vehicles*. Military Operations Research Symposium, Quantico, Virginia, 10 – 12 Jun 2003.

Journal Publications

DeLong, Suzanne O. and Donald E. Brown. *The Application Of A Terrain Based Tracker To Multiple Air Targets In A Sparse Data Environment*, Paper submitted November 2002 for the MORS Rist Prize and invited to be published in the Military Operations Research Journal.

DeLong, Suzanne O.* and Roger C. Burk*. *Automating Data Collection for the ABET Self-Study and Beyond*, Paper submitted January 2003 and under review May 2003 to the Journal of Engineering Technology.

DeLong, Suzanne O.* and Bob Foote*. *Computing Retention and Reacquisition Times for Table VIII Tank Gunnery Skill*, Paper submitted May 2003 to be published in the Military Operations Research Journal.

DeLong, Suzanne O.*, Eric Tollefson*, and Roger Burk*. *Modeling of HEL Weapons in Army Combat Simulations*, Paper to be published in the Directed Energy Professional Society Journal

DRISCOLL, PATRICK J., PH.D.

Refereed Publications

Driscoll, Patrick J.* and Edward Pohl*. 2002. "Modeling the Decision Quality in Sensor-to-Shooter (STS) Networks for Unattended Ground Sensor Clusters." *Proceedings of the Seventh International Conference on Information Quality*, Massachusetts Institute of Technology, Cambridge, MA.

Conference Presentations

Driscoll, P.J.* and E. Pohl.* "A mathematical programming approach to reliability systems design." International Federation of Operational Research Societies (IFORS), Edinburgh, Scotland, July, 2002.

Driscoll, P.J.* and E. Pohl.* "Modeling the Decision Quality in Sensor-to-Shooter (STS) Networks for Unattended Ground Sensor Clusters." Seventh International Conference on Information Quality (ICIQ), MIT, Cambridge, Massachusetts, November, 2002.

Awards

Lamm, Linda, M. J.*, Gregory A. Lamm*, and Patrick Driscoll.* *Networked Unattended Ground Sensor Fields: Tradeoff Study and Configuration Rules Methodology*. Technical Report, Department of Systems Engineering, United States Military Academy, West Point, NY, June 2002. MORS Barchi Prize Finalist.

Professional Society Officer Positions

Chairperson, INFORMS COMAP Committee, a subcommittee of the INFORMS Educational Committee.

Number of Refereed Conference Proceedings Publications you reviewed: 3

FOOTE, BOBBIE LEON, PH.D.

Refereed Journal Publications

Ingalls, Ricki G. and Bobbie L. Foote. "Control Based Life-Cycle Forecasting" Accepted by *IEEE Transactions on Electronics Packaging Manufacturing*, 2003.

Glen, Andrew G. and Bobbie L. Foote. "Determining the Contribution of New Components Added in Parallel to a Parallel System", Accepted by the *International Journal of Pure And Applied Mathematics*, 2003.

Refereed Proceedings

Foote, Bobbie Leon and Andrew G. Glen. "A Distribution Free Test of Censored Data", Proceedings of the IERC, May 18-21, Portland, OR., 2003.

Ingalls, Ricki, G., and Bobbie L. Foote. , "Reducing the Bull Whip Effect in Supply Chain With Control Based Forecasting", Proceedings of the IERC, May 18-21, Portland , OR. 2003.

Conference Presentations

Pohl, Edward*, Andrew G. Glen, and Bobbie L. Foote*. " Estimation of Parameters for Complex Circuits Having Masked Data", IERC, May 18-21, Portland, OR., 2003.

Glen, Andrew and Bobbie L. Foote., " Goodness of Fit For Censored Data", presented to the MORS Conference, Oct 16, Albuquerque, N.M., 2002.

GAY, RALPH H. III, PH.D., LIEUTENANT COLONEL

Conference Presentations

Gay, R., Phillips, D, Davis, B., Sui, D., "*Economic and Environmental Impacts of the Emerging Digital Economy.*" Annual Institute of Industrial Engineering Conference. 2002, Orlando, Florida.

Gay, R., Davis, B., Phillips, D, Sui, D., "*Exploring the Economic and Environmental Impacts of the New Digital Economy.*" INFORMS Annual Conference, November 2002, San Jose, California.

Refereed Conference Proceedings Publications

Sui, D.Z., R. Gay, and D.T. Phillips. 2002. *Environmental Impacts of E-commerce: The case of software sales.* International Symposium on IT and Environment. Tokyo, Japan, Sept. 19-21.

DeLong, S.*, Petitt, R., Gay, R.*, Klimack, W.*, "*Increased Lethality Study for Future and Current Fighting Vehicles*" Military Operation Research Society Symposium, June 2003, Quantico, Virginia.

Books or Book Chapters

Gay, Ralph H., *Exploring the Economic and Environmental Impact of the Digital Economy*, Dissertation, Texas A&M University, College Station, Texas, 2002.

Refereed Publication

Gay, R., Davis, B., Phillips, D, Sui, D, *Modeling Paradigms for the Environmental Impacts of the Emerging Digital Economy*, accepted to the Journal of Organizational Computing and Electronic Commerce.

Number of Refereed Journal Publications Reviewed: 1

KLIMACK, WILLIAM K., PH.D., Colonel

Awards

Elected to Phi Kappa Phi Honor Society, April 2003.

Non-Refereed Publications

Klimack, William K. "Review of Gulledge Report for PM Logistics Information Systems." Memorandum Report Number MR-03-04. Operations Research Center of Excellence, Department of Systems Engineering, United States Military Academy, 23 June 2003.

Conference Presentations

Klimack, William K., and Jack M. Kloeber, Jr. "Military Relative Risk Aversion," INFORMS Annual Conference, San Jose, California, 18 November 2002

Klimack, William K. "Military Relative Risk Aversion," 70th MORSS, MCB Quantico, Virginia, June 2003.

Klimack, William K. "Hybrid Value-Utility Model," INFORMS Annual Conference, Atlanta, Georgia, accepted for November 2003.

Klimack, William K. "The ORCEN at USMA," INFORMS Annual Conference, Atlanta, Georgia, accepted for November 2003.

Klimack, William K. "Taking a bite of the apple: Examining Jaguar OS in a WINTEL world," INFORMS Annual Conference, Atlanta, Georgia, accepted for November 2003.

Klimack, William K. "FCS Unit Set Fielding," INFORMS Annual Conference, Atlanta, Georgia, accepted for November 2003.

Farrell, Chris*, and William K Klimack*. "Interactive Multimedia Instruction for Military Education," INFORMS Annual Conference, Atlanta, Georgia, accepted for November 2003.

Farrell, Chris*, and William K Klimack*. "Interactive Multimedia Instruction for Military Education," I/ITSEC 25th Annual Conference, Orlando, Florida, accepted for December 2003.

Client Presentations

Klimack, William K. "FCS Unit Set Fielding," Army G8, 17 May 2003.

Klimack, William K. "FCS Unit Set Fielding," CG TRADOC, June 2003.

Professional Society Officer Positions

Member of the Executive Board, Military Applications Society, Institute for Operations Research and Management Science.

Session Chair, INFORMS Annual Conference, Atlanta, GA, October 2003

Advisor for Working Group 28, Decision Analysis, Military Operations Research Society

Member of Board of Directors, National Speleological Society.

Member of the Science Advisory Board, Explorers Club.

Number of Refereed Journal Publications Reviewed: 1.

KLINGAMAN, RANDALL R., M.S., Major

Conference Presentations

Klingaman, Randall R.*, Willie J. McFadden II*, *Agent Based Models: An Alternative Simulation Tool for Engineering Managers*. ASEM National Conference, Tampa Bay, FL, 2-4 OCT 2002.

Klingaman, Randall R., Romain Morley, Tawofik Ghazal, Emiko Terry, *Soldier Tactical Mission System Combat Effectiveness*. Systems and Information Engineering Design Symposium, University of Virginia, 24-26 APR 2003.

Klingaman, Randall R., *Soldier Tactical Mission System Combat Effectiveness Evaluation*. 71st MORS Symposium, Quantico, VA, 10-12 JUN 2003

**KWINN, MICHAEL J. JR., PH.D., Lieutenant Colonel
Refereed Journal Publications**

Brockett, P. L. Cooper, W. W., Kumbhakar, S., Kwinn, M. J.*, and McCarthy, D.*,
“Alternative Statistical Regression Studies of the Effects of Joint and Service
Specific Advertising on Military Recruitment”, submitted for second review in
the Journal of the Operations Research Society (JORS), January 2003.

Refereed Conference Proceedings:

Donovan, S., Mahoney, T., Pelletier, N., Schmidt, M., and Kwinn, M. J., “A Systems
Approach to John Wayne Airport Security”, University of Virginia Student
Research Conference, April 2003.

Kwinn, M. J.* , Pohl, E. A.* , Carlton, W. B.* , McGinnis, M. L.* , “Capstone Design in
Education: Systems Engineering and the West Point Way”, Proceedings of the
International Conference on Systems Engineering (INCOSE) Conference, August
2002.

Beach, J., Nogic, D., Rains, M., Williams, S., and Kwinn, M. J., “Information
Technology Training”, Proceedings of the International Conference on Systems
Engineering (INCOSE) Conference, August 2002.

Non-Refereed Conference Presentations

Brockett, P., Cooper, W., Kumbhakar, S., Kwinn, M. J.* , and Layton, B.* , “Stochastic
Frontier Analysis and Military Recruiting”, Presentation to the Hawaii
International Conference on Statistics, June 2003.

Donovan, S., Mahoney, T., Pelletier, N., Schmidt, M., and Kwinn, M. J., “Statistics and
Simulation for Baggage Screening Analysis”, Presentation to the Hawaii
International Conference on Statistics, June 2003.

Donovan, S., Mahoney, T., Pelletier, N., Schmidt, M., and Kwinn, M. J., “Using
Simulation to Analyze Airport Baggage Screening System Alternatives”,
Presentation to the Military Operations Research Society, June 2003.

**LAMM, GREGORY A., M.S., Major
Refereed Journal Publications**

Haimes, Yacov Y., Thomas A. Longstaff, and Gregory A. Lamm. *Balancing Promise
and Risk to Information Assurance in Joint Vision 2020*. Military Operations
Research Society (MORS) Journal, Volume 7, Number 3. 2002.

Haimes, Yacov Y., and Gregory A. Lamm. *Assessing and Managing Risks to
Information Assurance: A Methodological Approach*. Systems Engineering
Journal, Volume 5, Number 4. 2002.

Non-Refereed Publications

Lamm, Gregory A. *Getting Back to the Basics for Tactical Communications at West
Point*. Technical Report ORCEN.

Buckingham, James*, Gregory Lamm*, Chris Green, Jacob Bailey and Dave Bunt.

Imagery Collection as an Enhancement to the Disposable, Air droppable, Meteorological Tower Array (DAMPTA) for Intelligence Gathering on the Battlefield. Technical Report ORCEN.

Refereed Conference Proceedings Publications

Lamm, Gregory*, Dave Bunt and James Buckingham*. *Benefits of Imagery Collection for Enhancing Intelligence Gathering.* 2003 Systems and Information Engineering Design Symposium. University of Virginia, VA. 2003.

Number of Refereed Journal Publications you reviewed: 2

Number of Refereed Conference Proceedings Publications you reviewed: 1

LAMM, LINDA M. J., M.S., Major

Conference Proceedings

Lamm, Linda, M. J.* , Gregory A. Lamm*, and Patrick Driscoll*. *Networked Unattended Ground Sensor Fields: Tradeoff Study and Configuration Rules Methodology.* Proceedings of the Tenth Annual U.S. Army Research Laboratory / United States Military Academy Technical Symposium, November, 2002.

MCCARTHY, DANIEL J., M.S ., Major

Refereed Conference Proceedings Publications

McCarthy, D. J.* , W. J. McFadden, II*, and M. L. McGinnis*. "Put Me in Coach; I'm Ready to Play! A Discussion of an Evolving Curriculum in Systems Engineering", presented and published in the proceeding of the 2003 INCOSE International Symposium, Crystal City, VA, June 2003.

Belknap, M. H. and D. J. McCarthy*. "Textbook Selection: A Methodological Approach," presented and published in the proceedings of the 2003 Industrial Engineering Research Conference, Portland, Oregon, May, 2003.

Brockett, P. L., W. W. Cooper, S. Kumbhakar, M. J. Kwinn, Jr.* , and D. McCarthy*. "Alternative Statistical Regression Studies of the Effects of Joint and Service Specific Advertising on Military Recruitment", submitted with revisions for publication in the Journal of the Operations Research Society (JORS), February, 2003.

Number of Textbooks reviewed: 1

PARNELL, GREGORY S., PH.D.

Refereed Journal Publications

Parnell, G., Engelbrecht, J., Szafranski R., & Bennett, E, "Improving Customer Support Resource Allocation", *Interfaces*, Vol 32, No. 3, May-June 2002, pp. 77-90

Refereed Conference Proceedings Publications

Snyder, F. J., Parnell, G. S., & Klimack, W. K., "Modeling the Cost Objective: Insight for Practitioners and Academicians, Annual International Symposium of the

International Council on Systems Engineering, Las Vegas, Nevada, July 28-August 1, 2002

Stokes, B., Parnell, G., Burk, R., "Techniques For Allocating Budgets In Large Organizations: Benefit, Pain Or Value?", Proceedings of the American Society for Engineering Management Conference 2002, Tampa, Florida, October 2-5, 2002.

Conference Presentations

Klingaman, R.* and Parnell, G. S.* , "Modeling Soldier Tactical Mission System Combat Effectiveness," Military Operations Research Society Symposium, United States Marine Corps, Quantico, VA, Jun 2003

Parnell, G. S.* , Stokes, B*, Carpenter, M, Kamon, M., Pigott, D., Army Capability Model, Military Operations Research Society Symposium, United States Marine Corps, Quantico, VA, Jun 2003

Client Presentations

Stokes, B*, and Parnell,G.* "Army Capability Model." Presentation to LTC Vince Badami , HQDA, DCSOPS (DAMO-ZR), May 9, 2003

Dr. Craig College, Deputy Assistant Secretary of the Army (Infrastructure Analyses), "BRAC 2005 Military Value", presentations in May, July and August 2003

Professional Society Officer Positions

President Elect, Decision Analysis Society, INFORMS, 2002-2004

Council Member, Decision Analysis Society of INFORMS, 2000-2002

Professional Service

Member, Technology Panel of the National Security Agency Advisory Board, 2003-present

Member, Signals Intelligence Directorate Technology Panel of the National Security Advisory Board, 2001-2003

Number of Refereed Journal Publications Reviewed: 8

POHL, EDWARD A., PH.D., Lieutenant Colonel

Journal Papers Submitted

Cassady, C. R., I. M. Iyoob, E. A. Pohl, K. Schneider. "A Generic Model of Equipment Availability under Imperfect Maintenance" Submitted to the *IEEE Transactions on Reliability*.

Cassady, C. R., E. A. Pohl, S. Jin. "Managing Availability Improvement Efforts with Importance Measures and Optimization", Submitted to the *IMA Journal of Management Mathematics on Maintenance, Replacement and Reliability*.

Journal Papers Published

Cassady, C. R., I. G. Takashi, E. A. Pohl. "Reliability Analysis for Intermittently Used Products", *International Journal of Modeling and Simulation*, Volume 23, Number 4, 2003.

Refereed Conference Papers

Pohl, E. A.* , C. R. Cassady, M. J. Kwinn, Jr.* . "A Selective Maintenance Model for Serial Manufacturing Systems Involving Multiple Maintenance Actions", *Proceedings of the 17th International Conference on Production Research*, August 2003.

Orman, S., C. R. Cassady, E. A. Pohl. "Exploring the Effects of Cannibalization on Fleet Performance", *Proceedings of the 2003 Industrial Engineering Research Conference*, Portland, OR, May 2003

Driscoll, P. J.* , and E. A. Pohl*. "Modeling the Decision Quality of Sensor to Shooter (STS) Networks", *Proceedings of the 7th International Conference on Information Quality*, Boston, MA, November 2002.

Tutorials

Cassady, C. R., and E. A. Pohl. "Introduction to Repairable System Modeling", IEEE Tutorial Notes, IEEE Tutorial Notes, *49th Reliability and Maintainability Symposium*, Tampa, FL. January 2003.

Presentations

Pohl, E. A., S. Ruflin, W. P. Murdock, C. R. Cassady. "Mean Residual Life Analysis of Aging Systems", *2003 Industrial Engineering Research Conference*, Portland, OR, May 2003.

Cassady, C.R., S. Orman, E. A. Pohl. "Exploring the Effects of Cannibalization on Fleet Performance", *2003 Industrial Engineering Research Conference*, Portland, OR, May 2003

Foote, B.L.* , E. A. Pohl*, A. G. Glen. "Estimation of Parameters for Complex Circuits having Masked Data", *2003 Industrial Engineering Research Conference*, Portland, OR, May 2003

Pohl, E.A. "Threats, Security, and Stochastic OR', Panel member and presenter. INFORMS 2002, San Jose, CA, November 2002

Driscoll, P.J.* and E. A. Pohl. "Modeling the Decision Quality of Sensor to Shooter (STS) Networks", *7th International Conference on Information Quality*, Boston, MA, November 2002.

Client Presentations

Pohl, E. A.* , S. DeLong*, B. L. Foote*, D. Smith. "Embedded Training Research Update", Presented to Ms. Silvia Rivera, PM Bradley, Mr. George Moore, TSM, PM Bradley, Mr. Lee Thompson, PM Abrams Training Devices, 24 March 2003

Pohl, E. A.* , B. L. Foote*, Bille, S., "Embedded Training Research", Presentation to CPT Frank Bridges,U.S. Army TACOM, Training Devices, 6 June 2003

Pohl, E. A., B. L. Foote*. "Embedded Training Research", VTC Presentation to Bradley and Abrams Embedded Training IPT, 16 July 2003

Professional Society Officer Positions

Associate Editor for *The IEEE Transactions on Reliability*

Associate Editor for *Military Operations Research Journal*

Director, *Institute of Industrial Engineering*, Quality Control and Reliability Networking Group.

Management Committee, IEEE Reliability and Maintainability Symposium

Number of Refereed Journal Publications Reviews: 4.

Number of Refereed Conference Proceedings Publications Reviews: 2.

STOKES, BRIAN J., M.S., Major**Refereed Conference Proceedings Publications**

Stokes, B.*, G. S. Parnell*. "Techniques for Allocating Budgets in Large Organizations: Benefit, Pain, or Value?", Proceedings of the American Society for Engineering Management Conference 2002, Tampa, Florida, October 2-5, 2002.

Non-Refereed Publications

Stokes, B.*, G. S. Parnell*. "Army Capability Model", US Military Academy, Department of Systems Engineering Final Report 2003

Stokes, B.*, T. Trainor*. "Fleet Operations Safety Assessment Tool (FOSAT)", US Military Academy, Department of Systems Engineering Final Report 2003

Conference Presentations

Stokes, B.*, G. S. Parnell*. "Techniques for Allocating Budgets in Large Organizations: Benefit, Pain, or Value?", American Society for Engineering Management Conference 2002, Tampa, Florida, October 2-5, 2002.

Stokes, B.*, G. S. Parnell*. "Working within a Budget: The Allocation of Limited Resources within Large Organizations", INFORMS Annual Meeting, 2002, San Jose, California, November 17-20, 2002.

Client Presentations

Stokes, B.*, G. S. Parnell*. "POM Prioritization", Presented to COL Boatner, HQDA, G3 (DAMO-ZR), April 10, 2003.

Stokes, B.*, T. Trainor*. "Fleet Assessment Tool", Presented to the Vice President for Safety, American International Group, April 28, 2002.

TRAINOR, TIMOTHY, PH.D., Lieutenant Colonel

Invited to participate at the Young Researchers Roundtable for the INFORMS Conference on Operations Research/Management Science Practices, *Creating Value in the Extended Enterprise*, May 4-6, 2003, Phoenix, Arizona.

Refereed Journal Publications

Hodgson, T.J., Barbra Melendez, Kristin A. Thoney, Timothy E. Trainor. *The Deployment Scheduling Analysis Tool (DSAT)*. Special Issue of Mathematical and Computer Modeling, Defense Transportation: Algorithms, Models and Applications for the 21st Century, to be published in Spring 2004.

Non-Refereed Publications

Buckingham, James*, Willie J. McFadden, II*, Michael Nowatkowski*, Timothy E. Trainor*. *Tackling Safety with Simulation*. IIE Solutions (magazine for the Institute of Industrial Engineers), September 2002.

Nowatkowski, Michael*, James Buckingham*, Willie J. McFadden, II*, Timothy E. Trainor*. *Simulation Supports Security Plans for Army Football*. Phalanx, the bulletin of Military Operations Research, September 2002.

Stokes, B.*, T. Trainor*. "Fleet Operations Safety Assessment Tool (FOSAT)", US Military Academy, Department of Systems Engineering Final Report 2003

Conference Presentations

Hodgson, T.J., Barbra Melendez, Kristin A. Thoney, Timothy E. Trainor. *The Deployment Scheduling Analysis Tool (DSAT)*. Presentation at the 16th International Federation of Operational Research Societies Conference (IFORS 2002), July 2002.

Magras, Patrick G.*, Timothy E. Trainor*. *Installation Risk and Vulnerability Assessment Tool*. Presentation at the 71st Military Operations Research Symposium (MORSS 2003), June 2003.

Client Presentation

Stokes, B.*, T. Trainor*. "Fleet Assessment Tool", Presented to the Vice President for Safety, American International Group, April 28, 2003.

Number of Refereed Journal Publications you reviewed: 2

TOLLEFSON, ERIC S., M.S., Captain**Non-Refereed Publications**

Burk, Roger C.*, Suzanne O. Delong*, and Eric S. Tollefson*. *Modeling of HEL Weapons in Army Combat Simulations*, DSE Technical Report, in preparation.

Conference Presentations

Burk, Roger C.*, Suzanne O. Delong*, and Eric S. Tollefson*. Presentation at the Directed Energy Professional Society Modeling and Simulation Conference. *Modeling of HEL Weapons in Army Combat Simulations*, Albuquerque, NM, 26-27 March 2003.

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Deputy Chief of Staff Training & Leader Development Directorate Army G-3	300 Army Pentagon Washington, DC 20310-0300	1
Deputy Chief of Staff for Logistics Army G-4	300 Army Pentagon Washington, DC 20310-0300	1
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Commander US Army Accessions Command (USAAC)	90 Ingalls Road – Bldg. 100 Ft. Monroe, VA 23651	1
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Director Defense Modeling & Simulation Office	1901 N. Beauregard Street, Suite 500 Alexandria, Virginia, 22311-1705, USA	1
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Director, HEL Joint Technology Office	901 University Boulevard SE – Suite 100 Albuquerque, NM 87106	1
Chief Resource Analysis and Integration Office Army G-3	HQDA- DCSOPS (DAMO-ZR) 400 Army Pentagon Washington, DC 20310-0400	1
Chief, Deployability Division	MTMCTEA 720 Thimble Shoals Blvd. Newport News, VA 23606-2574	1
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Dr. Stephen Landowne, Associate Dean, Academic Research Division	MADN-ARD USMA, Bldg 600, Room 15 West Point, NY 10996	1
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